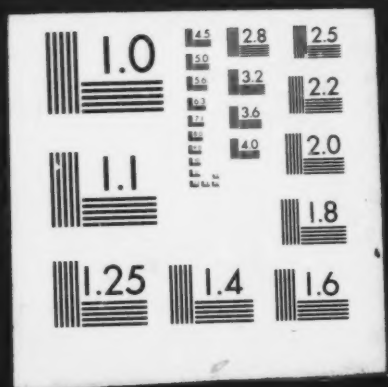


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Industrial Process Profiles for  
Environmental Use: Chapter 6  
The Industrial Organic Chemicals Industry

Research Triangle Inst, Research Triangle Park, N C

Prepared for

Industrial Environmental Research Lab -Cincinnati, Ohio

Feb 77



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| 16. Abstract (Limit: 200 words)<br>The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the U.S. Entries for each industry are in consistent format and form separate chapters of the study. Industrial organic chemicals are the product of at least one chemical reaction in this industry and will undergo at least one additional treatment step in a downstream processing industry. These compounds are intermediate materials in the manufacture of such products as plastics, synthetic fibers, pharmaceuticals and surfactants among others. The industry is discussed in terms of ten feedstock groups: benzene, butylenes, sources of cresylic acids, ethylene, methane, naphthalene, paraffins, propylene, toluene and xylenes. Ten chemical trees, ten process flow sheets and 365 process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on function, input materials, operating parameters, utilities, waste streams, EPA Source Classification Code and references. Data related to the subject matter, including company, product and raw material data, are included as appendices. |  |                                    |  |                                                  |  |                                                                  |  |
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EPA-600/2-77-023f  
February 1977

Environmental Protection Technology Series

**INDUSTRIAL PROCESS PROFILES FOR  
ENVIRONMENTAL USE: Chapter 6.  
The Industrial Organic  
Chemicals Industry**



REPRODUCED BY  
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INDUSTRIAL PROCESS PROFILES  
FOR ENVIRONMENTAL USE  
CHAPTER 6  
THE INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

by

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| 2-Naphthalenesulfonic acid                 | 218                                |
| 1-Naphthol                                 | 212                                |
| 2-Naphthol                                 | 219                                |
| 1-Naphthylamine                            | 211                                |
| Neopentanoic acid                          | 74                                 |
| o- and p-Nitroanilines                     | 29                                 |
| Nitroanisoles (ortho- and para-)           | 309                                |
| Nitrobenzene                               | 25                                 |
| Nitrobenzoic acids (o-, m-, p-)            | 339                                |



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| <u>Chemical</u>                                  | <u>Process Description Numbers</u> |
|--------------------------------------------------|------------------------------------|
| m-Nitrobenzoic acid                              | 329                                |
| Nitroparaffins (C <sub>1</sub> -C <sub>3</sub> ) | 237                                |
| 1-Nitronaphthalene                               | 210                                |
| Nitrophenols (ortho- and para-)                  | 307                                |
| Nitrotoluene                                     | 338                                |
| Nitroxylene (o-, m-, p-)                         | 363                                |
| Nonene                                           | 264                                |
| Nonylphenol                                      | 311                                |
| Octylphenol                                      | 312                                |
| Oxo alcohols                                     | 188                                |
| Oxo aldehydes                                    | 187                                |
| Paraldehyde                                      | 93                                 |
| Pentaerythritol                                  | 94                                 |
| Pentynes                                         | 244                                |
| Perchloroethylene                                | 140, 180, 234, 235                 |
| Perchloromethyl mercaptan                        | 165                                |
| Phenetidines (ortho- and para-)                  | 308                                |
| Phenol                                           | 8, 37, 78, 295, 326                |
| Phenolic pitch                                   | 78                                 |
| Phenols (higher methylated)                      | 82                                 |
| Phenolsulfonic acids (ortho- and para-)          | 314                                |
| m-Phenylenediamine                               | 27                                 |
| o-Phenylenediamine                               | 28                                 |
| p-Phenylenediamine                               | 30                                 |
| Phosgene                                         | 189                                |
| Phthalic anhydride                               | 220, 360                           |
| Phthalimide                                      | 225                                |

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| <u>Chemical</u>                            | <u>Process Description Numbers</u> |
|--------------------------------------------|------------------------------------|
| Phthalonitrile                             | 222                                |
| $\beta$ -Picoline                          | 100                                |
| Piperazine                                 | 154                                |
| Polybutenes                                | 239                                |
| Polyethylene glycol                        | 155                                |
| Polypropylene glycol                       | 288                                |
| 2-Propanol                                 | 267                                |
| Propionaldehyde                            | 229                                |
| Propanoic acid                             | 126, 227                           |
| n-Propyl alcohol                           | 227                                |
| n-Propyl amines                            | 228, 231                           |
| n-Propyl chloride                          | 230                                |
| Propylene chlorohydrin                     | 285, 316                           |
| Propylene dichloride                       | 322                                |
| Propylene glycols (mono- and di-)          | 287                                |
| Propylene oxide                            | 286, 320                           |
| Pyridine                                   | 100                                |
| <br>Resorcinol                             | <br>23                             |
| <br>Salicylic acid (and methyl salicylate) | <br>303A                           |
| Sodium acetate                             | 106                                |
| Sodium benzoate                            | 331                                |
| Sodium carbolate (crude)                   | 77                                 |
| Sodium carboxymethyl cellulose             | 112                                |
| Sodium chloroacetate                       | 109                                |
| Sodium formate                             | 190                                |
| Sodium phenate                             | 301                                |
| Sorbic acid                                | 96                                 |

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| <u>Chemical</u>                       | <u>Process Description Numbers</u> |
|---------------------------------------|------------------------------------|
| Styrene                               | 3                                  |
| Succinic acid                         | 39                                 |
| Succinonitrile                        | 275                                |
| Sulfanilic acid                       | 35                                 |
| Sulfolane                             | 60                                 |
| Synthesis gas                         | 181, 182                           |
|                                       |                                    |
| Terephthalic acid                     | 362A                               |
| 1,1,2,2-Tetrachloroethane             | 179                                |
| Tetrachlorophthalic anhydride         | 221                                |
| Tetraethyl lead                       | 116, 117                           |
| Tetrahydronaphthalene                 | 215                                |
| Tetrahydrophthalic anhydride          | 40                                 |
| p-Toluenesulfonamide                  | 358                                |
| Toluenesulfonic acids                 | 79                                 |
| p-Toluenesulfonyl chloride            | 357                                |
| Toluidines                            | 341                                |
| 2,4,6-Trichloroaniline                | 19                                 |
| Trichlorobenzenes                     | 6                                  |
| 1,1,2-Trichloroethane                 | 137, 138                           |
| Trichloroethylene                     | 140, 180                           |
| Trichlorofluoromethane                | 163                                |
| 1,2,3-Trichloropropane                | 321                                |
| 1,1,2-Trichloro-1,2,2-Trifluoroethane | 141                                |
| Triethylene glycol monomethyl ether   | 149                                |
| Triethylene glycol dimethyl ether     | 150                                |
|                                       |                                    |
| Urea                                  | 183, 184                           |

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| <u>Chemical</u>                | <u>Process Description Numbers</u> |
|--------------------------------|------------------------------------|
| Vinyl acetate                  | 95, 174                            |
| Vinyl chloride                 | 133                                |
| Vinylidene chloride            | 139                                |
| Vinyl toluenes                 | 130                                |
|                                |                                    |
| Xylenes (ortho-, meta-, para-) | 349, 359                           |
| 2,6-Xylenol                    | 297                                |
| Xylenols                       | 78, 82                             |
| Xylidines                      | 364                                |

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INDUSTRY DESCRIPTION

6-1

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## INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

### INDUSTRY DESCRIPTION

A precise definition of the Industrial Organic Chemicals Industry is difficult to formulate because of the close interrelationship between it and other elements of the petrochemical industry in general. For the purpose of this study, industrial organic chemicals are defined as solvents or chemical intermediates prepared from products of the Basic Petrochemicals Industry (Chapter 5). Industrial organic chemicals are the product of at least one chemical reaction in this industry and will undergo at least one additional treatment step in a downstream processing industry. Thus, these compounds are intermediate materials in the manufacture of such products as plastics, synthetic fibers, pharmaceuticals, and surfactants from basic petrochemicals such as olefins, aromatics and paraffins.

The Industrial Organic Chemicals Industry does not lend itself to separation into various segments, but the chemical trees, flow sheets and process descriptions are grouped according to feedstock. This arrangement according to feedstock results in ten groups of processes or sections: benzene, butylene, cresol, ethylene, methane, naphthalene, paraffin, propylene, toluene and xylene. Each section is preceded by a chemical tree and flow sheets illustrating products and processing steps described. The chapter includes 364 processes describing the production of 442 industrial organic chemicals.

The principal feedstocks to the industry are the hydrocarbon products (olefins, paraffins, and aromatics) from the Basic Petrochemicals Industry



described in Chapter 5. Many of these feedstocks come to the industry as mixtures of olefins, paraffins and/or aromatics and must go through a separation process such as distillation, extraction, absorption or crystallization to separate the components. The flow sheets and process descriptions for this industry include separation processes as well as the conversion processes used in manufacturing the organic chemicals.

There are limited data available describing precisely the particular group of companies defined in this chapter as producers of industrial organic chemicals. In a separate study performed under EPA Contract No. 68-02-1319, Task 51, an intensive effort was made to characterize the industry defined herein. The 1976 Directory of Chemical Producers and additional sources of information were used to compile data concerning production facilities for some 358 industrial organic chemicals. The product slate described in that study differs only slightly from the one defined in this chapter. The study identified 260 companies with 544 plant sites for the manufacture of 442 industrial organic chemicals. The product slate is given in Appendix D and the list of producers in Appendix E.

Because of the close functional and even physical relationships between manufacturing establishments in the Basic Petrochemicals, industrial organic chemicals and numerous downstream processing industries, classification of industrial organic chemical manufacturers according to a single SIC code is impossible. The Index to Industrial Organic Chemicals (pages iv through xix) and the Industrial Chemicals and Solvents Glossary (Appendix A) indicate that manufacturing establishments are classified in SIC codes 2865 and 2869. However, tenancy in these classifications is shared with establishments

engaged primarily in manufacturing dyes and organic pigments (Chapter 7), basic petrochemicals (Chapter 5), plasticizers (Chapter 13), and pesticides (Chapter 8). The only available data on employment statistics and energy and raw materials consumption are compiled for the groups of companies classified in these SIC codes.

Data published in the 1972 Census of Manufacturers indicate there were 173 establishments classified in SIC code 2865 (Cyclic Crudes and Intermediates, Dyes and Organic Pigments). Of these, 49 were classified under product code 28651 (Cyclic Intermediates) which is within the scope of the chapter. The 1972 Census of Manufacturers also indicates there were 514 establishments classified in SIC code 2869 (Industrial Organic Chemicals, not elsewhere classified). Some 331 of these appear to produce chemicals defined as products of this industry: 42 were producers of miscellaneous cyclic chemicals (product code 28691); 168 were producers of miscellaneous acyclic chemicals, except urea (product code 28692); 69 produced synthetic organic chemicals, not elsewhere classified, not bulk (product code 28693); and 52 were producers of ethyl alcohol and other industrial chemicals not elsewhere classified (product code 28695).

Figures given for establishments classified in SIC codes 2865 and 2869 include establishments producing materials outside the scope of this study. Some establishments may appear in any or all of the several industry and product codes cited above. For these reasons, no precise accounting of total industrial populations may be derived from SIC category data, either by summation or by elimination.

Information relating to the physical size of industrial organic chemical manufacturing facilities is not available, because these operations are generally completely integrated with facilities classified in other industries.

Employment statistics for manufacturing establishments classified in SIC codes 2865 and 2869 are presented in Tables 1 and 2. The caveat imposed above applies also to data contained in these tables. Employment statistics for selected product classification codes are presented in Table 1. Statistics describing employment size of establishments specific for selected product codes are not available, but composite statistics for SIC code 2865 and 2869 are contained in Table 2.

Production data for materials classified under product codes 2865 and 2869 are presented in Table 3. This table includes data reported not only by establishments classified in SIC codes 2865 and 2869 but also by establishments classified in other industries and shipping these products as "secondary" products. Certain of the data relating to products outside the scope of this chapter are included in order to demonstrate the interrelationship and convolutions of processes and products within the petrochemical industry in general and the Industrial Organic Chemicals Industry in particular. Data for 1967 as well as 1972 production are presented and indicate an almost universal pattern of growth.

A tabulation of materials consumed in 1972 by establishments in SIC codes 2865 and 2869 is presented in Table 4. This tabulation includes the consumption of not only process chemicals and raw materials, but also other materials, supplies and machinery necessary to the presentation of a product ready for shipment.

TABLE 1. GENERAL STATISTIC FOR ESTABLISHMENTS, BY  
INDUSTRY SPECIALIZATION AND PRIMARY PRODUCT CLASS SPECIALIZATION: 1972

This table presents selected statistics for establishments according to their degree of specialization in products primary to their industry. The measures of plant specialization shown are (1) industry specialization—the ratio of primary product shipments to total product shipments, primary plus secondary, for the establishments, and (2) product class specialization—the ratio of the largest primary product class shipments to total product shipments, primary plus secondary, for the establishments. See the source for method of computing these ratios. Statistics for establishments with specialization ratios of less than 75 percent are included in total lines but are not shown as a separate class. In addition, data may not be shown, for some industries, product classes or specialization ratios for various reasons; e.g., to avoid disclosure of individual company data.

| Industry or product class code | Industry or product class by percent of specialization                                 | Establishments (number) | All employees  |                           | Production workers |                      |                         | Value added by manufacture (million dollars) | Cost of materials (million dollars) | Value of shipments (million dollars) | Capital expenditures, new (million dollars) |
|--------------------------------|----------------------------------------------------------------------------------------|-------------------------|----------------|---------------------------|--------------------|----------------------|-------------------------|----------------------------------------------|-------------------------------------|--------------------------------------|---------------------------------------------|
|                                |                                                                                        |                         | Number (1,000) | Payroll (million dollars) | Number (1,000)     | Man-hours (millions) | Wages (million dollars) |                                              |                                     |                                      |                                             |
| 2865                           | Cyclic crudes and intermediates                                                        |                         |                |                           |                    |                      |                         |                                              |                                     |                                      |                                             |
|                                | Entire industry.....                                                                   | 173                     | 28.2           | 317.6                     | 18.7               | 38.4                 | 190.9                   | 925.2                                        | 1 109.7                             | 2 044.5                              | 158.7                                       |
|                                | Establishments with 75% or more specialization.....                                    | 161                     | 16.8           | 181.1                     | 11.1               | 22.7                 | 108.6                   | 512.6                                        | 622.7                               | 1 141.3                              | 80.4                                        |
| 28651                          | Cyclic intermediates (Primary product class of establishments).....                    | 49                      | 11.3           | 139.1                     | 7.4                | 15.6                 | 81.5                    | 504.4                                        | 659.3                               | 1 176.4                              | 116.1                                       |
|                                | Establishments with 75% or more specialization.....                                    | 26                      | 3.6            | 43.0                      | 2.2                | 4.8                  | 24.3                    | 195.7                                        | 253.1                               | 463.3                                | 45.5                                        |
| 2869                           | Industrial organic chemicals, nec                                                      |                         |                |                           |                    |                      |                         |                                              |                                     |                                      |                                             |
|                                | Entire industry.....                                                                   | 514                     | 101.7          | 1 240.2                   | 64.1               | 129.1                | 707.6                   | 4 965.1                                      | 4 209.5                             | 9 179.1                              | 645.4                                       |
|                                | Establishments with 75% or more specialization.....                                    | 407                     | 42.3           | 503.9                     | 27.6               | 56.1                 | 299.7                   | 2 299.5                                      | 2 059.3                             | 4 371.2                              | 224.3                                       |
| 28691                          | Miscellaneous cyclic chemical products (Primary product class of establishments).....  | 42                      | 5.7            | 61.1                      | 3.7                | 7.5                  | 35.9                    | 190.4                                        | 187.8                               | 378.4                                | 26.2                                        |
|                                | Establishments with 75% or more specialization.....                                    | 21                      | 1.8            | 19.8                      | 1.0                | 2.1                  | 9.7                     | 46.2                                         | 52.9                                | 101.0                                | 8.3                                         |
| 28692                          | Miscellaneous acyclic chems., exc. urea (Primary product class of establishments)..... | 168                     | 78.6           | 981.3                     | 50.2               | 101.6                | 570.6                   | 4 080.7                                      | 3 298.7                             | 7 399.4                              | 508.1                                       |
|                                | Establishments with 75% or more specialization.....                                    | 93                      | 17.1           | 215.5                     | 11.4               | 23.0                 | 129.2                   | 1 048.0                                      | 1 020.7                             | 2 071.2                              | 120.7                                       |
| 28693                          | Synthetic organic chems., nec, not bulk (Primary product class of establishments)..... | 60                      | 9.7            | 112.6                     | 5.6                | 11.4                 | 59.2                    | 288.6                                        | 431.3                               | 713.9                                | 46.3                                        |
|                                | Establishments with 75% or more specialization.....                                    | 39                      | 2.0            | 21.6                      | 1.1                | 2.3                  | 10.8                    | 83.2                                         | 117.1                               | 201.0                                | 15.2                                        |
| 29695                          | Ethyl alcohol, other Indust. organic chems., nec.....                                  |                         |                |                           |                    |                      |                         |                                              |                                     |                                      |                                             |
|                                | (Primary product class of establishments).....                                         | 52                      | 3.1            | 30.5                      | 1.7                | 3.3                  | 13.7                    | 66.9                                         | 85.8                                | 152.3                                | 5.7                                         |
|                                | Establishments with 75% or more specialization.....                                    | 31                      | 2.0            | 18.1                      | 1.1                | 2.1                  | 8.7                     | 45.2                                         | 49.5                                | 93.9                                 | 5.0                                         |

Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, "1972 Census of Manufacturers", Industrial Organic Chemicals, Sic Industry Group 286.

TABLE 2. GENERAL STATISTICS, BY EMPLOYMENT SIZE OF ESTABLISHMENTS: 1972

| Item                                           | Establishments<br>(number) | All employees     |                                 | Production workers |                         | Value<br>added by<br>manufac-<br>ture (million<br>dollars) | Cost of<br>materials<br>(million<br>dollars) | Value of<br>shipments<br>(million<br>dollars) | Capital<br>expendi-<br>tures,<br>new<br>(million<br>dollars) | End-of-<br>year<br>inventories<br>(million<br>dollars) |
|------------------------------------------------|----------------------------|-------------------|---------------------------------|--------------------|-------------------------|------------------------------------------------------------|----------------------------------------------|-----------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------|
|                                                |                            | Number<br>(1,000) | Payroll<br>(million<br>dollars) | Number<br>(1,000)  | Man-hours<br>(millions) | Wages<br>(million<br>dollars)                              |                                              |                                               |                                                              |                                                        |
| 2865--Cyclic crude and intermediates           | 173                        | 28.2              | 317.6                           | 18.7               | 38.4                    | 190.9                                                      | 925.2                                        | 1 109.7                                       | 2 046.5                                                      | 158.7                                                  |
| Establishments, total.....                     |                            |                   |                                 |                    |                         |                                                            |                                              |                                               |                                                              | 355.6                                                  |
| Establishments with an average of -            |                            |                   |                                 |                    |                         |                                                            |                                              |                                               |                                                              |                                                        |
| 1 to 4 employees.....E7                        | 23                         | (2)               | .4                              | (2)                | .1                      | .3                                                         | 1.2                                          | 1.5                                           | 2.9                                                          | .3                                                     |
| 5 to 9 employees.....E8                        | 16                         | .1                | 1.1                             | .1                 | .2                      | .7                                                         | 3.2                                          | 4.4                                           | 7.6                                                          | .6                                                     |
| 10 to 19 employees.....E9                      | 17                         | .2                | 2.4                             | .2                 | .3                      | 1.3                                                        | 11.1                                         | 18.6                                          | 23.4                                                         | 1.1                                                    |
| 20 to 49 employees.....E1                      | 27                         | .9                | 8.8                             | .6                 | 1.2                     | 5.2                                                        | 29.3                                         | 47.2                                          | 75.8                                                         | 3.9                                                    |
| 50 to 99 employees.....E2                      | 29                         | 1.9               | 20.3                            | 1.3                | 2.8                     | 12.4                                                       | 60.6                                         | 104.1                                         | 165.7                                                        | 5.3                                                    |
| 100 to 249 employees.....E3                    | 29                         | 5.0               | 53.7                            | 3.0                | 6.4                     | 29.3                                                       | 213.1                                        | 253.2                                         | 474.4                                                        | 53.7                                                   |
| 250 to 499 employees.....E4                    | 17                         | 6.1               | 64.5                            | 4.1                | 8.5                     | 40.9                                                       | 239.4                                        | 291.2                                         | 529.5                                                        | 53.4                                                   |
| 500 to 999 employees.....E5                    | 9                          | 5.9               | 72.0                            | 3.8                | 7.8                     | 39.7                                                       | 165.5                                        | 204.0                                         | 375.3                                                        | 21.1                                                   |
| 1,000 to 2,499 employees.....E6                | 6                          | 7.9               | 94.3                            | 5.6                | 11.1                    | 61.1                                                       | 198.0                                        | 185.4                                         | 386.1                                                        | 19.3                                                   |
| Establs. covered by admin. record <sup>1</sup> | 26                         | .1                | 1.1                             | .1                 | .2                      | .6                                                         | 3.1                                          | 3.5                                           | 6.7                                                          | .9                                                     |
| 2869--Industrial organic chemicals, nec        | 514                        | 101.7             | 1 240.2                         | 66.1               | 129.1                   | 707.6                                                      | 4 965.1                                      | 4 209.5                                       | 9 179.1                                                      | 645.4                                                  |
| Establishments, total.....                     |                            |                   |                                 |                    |                         |                                                            |                                              |                                               |                                                              | 1 075.9                                                |
| Establishments with an average of -            |                            |                   |                                 |                    |                         |                                                            |                                              |                                               |                                                              |                                                        |
| 1 to 4 employees.....E7                        | 119                        | .2                | 2.5                             | .2                 | .3                      | 1.3                                                        | 7.9                                          | 5.9                                           | 13.7                                                         | 31.7                                                   |
| 5 to 9 employees.....E8                        | 50                         | .3                | 3.6                             | .2                 | .4                      | 1.9                                                        | 11.4                                         | 17.8                                          | 28.9                                                         | (6)                                                    |
| 10 to 19 employees.....E9                      | 50                         | .7                | 7.2                             | .5                 | .9                      | 3.9                                                        | 22.7                                         | 31.2                                          | 54.6                                                         | 3.7                                                    |
| 20 to 49 employees.....E1                      | 82                         | 2.7               | 28.6                            | 1.6                | 3.3                     | 14.7                                                       | 125.9                                        | 125.3                                         | 246.3                                                        | 29.6                                                   |
| 50 to 99 employees.....E2                      | 56                         | 4.0               | 45.3                            | 2.3                | 4.9                     | 23.5                                                       | 195.5                                        | 260.0                                         | 457.7                                                        | 49.4                                                   |
| 100 to 249 employees.....E3                    | 77                         | 12.0              | 135.7                           | 7.4                | 15.5                    | 78.9                                                       | 703.9                                        | 744.3                                         | 1 429.4                                                      | 64.9                                                   |
| 250 to 499 employees.....E4                    | 31                         | 11.1              | 127.8                           | 7.2                | 15.3                    | 77.4                                                       | 550.0                                        | 586.4                                         | 1 139.7                                                      | 64.9                                                   |
| 500 to 999 employees.....E5                    | 24                         | 16.6              | 204.5                           | 11.1               | 22.0                    | 126.0                                                      | 869.1                                        | 672.4                                         | 1 542.5                                                      | 104.7                                                  |
| 1,000 to 2,499 employees.....E6                | 19                         | 30.4              | 383.5                           | 19.0               | 37.2                    | 217.7                                                      | 1 515.3                                      | 1 054.4                                       | 2 580.3                                                      | 195.0                                                  |
| 2,500 employees or more.....E7                 | 6                          | 23.5              | 301.6                           | 14.5               | 28.6                    | 164.6                                                      | 963.4                                        | 711.8                                         | 1 686.1                                                      | 144.7                                                  |
| Establs. covered by record <sup>1</sup>        | 99                         | .3                | 2.7                             | .2                 | .3                      | 1.5                                                        | 9.2                                          | 8.0                                           | 17.1                                                         | 1.4                                                    |

(D) Withheld to avoid disclosing figures for individual companies. Data for this item are included in the underscored figures above. (Z) Less than half of the unit of measurement shown.

<sup>1</sup> Report forms were not mailed to companies that operated only one establishment--generally single-unit companies with less than 10 employees. Payroll and sales for 1972 were obtained from administrative records supplied to other agencies of the Federal Government. These payroll and sales data were then used in conjunction with industry averages to estimate the balances of the items shown in the table. Data are also included in the respective size classes shown for this industry.

Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, "1972 Census of Manufactures", Industrial Organic Chemicals, SIC Industry Group 286. See source for explanation of terms.



**TABLE 3. PRODUCTS AND PRODUCT CLASSES--**  
**VALUE OF SHIPMENTS BY ALL PRODUCERS: 1972 AND 1967**

(Includes quantity and value of the products reported not only by establishments classified in this industry, but also by establishments classified in other industries, and shipping these products as "secondary" products. See source for explanation of term.

| 1972<br>product<br>code | Product                                                                                                           | 1972                                                               |                                 |                                 | 1967                                                               |                                 |                                 |
|-------------------------|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------|---------------------------------|--------------------------------------------------------------------|---------------------------------|---------------------------------|
|                         |                                                                                                                   | Total product<br>shipments<br>including<br>interplant<br>transfers | Commercial<br>shipments<br>only | Interplant<br>transfers<br>only | Total product<br>shipments<br>including<br>interplant<br>transfers | Commercial<br>shipments<br>only | Interplant<br>transfers<br>only |
|                         |                                                                                                                   | (million dollars)                                                  | (million dollars)               | (million dollars)               | (million dollars)                                                  | (million dollars)               | (million dollars)               |
| 2865- --                | CYCLIC CRUDE AND INTERMEDIATES,<br>TOTAL.....                                                                     | 2,332.4                                                            | (X)                             | (X)                             | 1,654.2                                                            | (X)                             | (X)                             |
| 28651 11                | Cyclic (coal tar) intermediates <sup>1</sup>                                                                      | 1,538.0                                                            | 1,151.7                         | 386.3                           | 1,066.1                                                            | 795.6                           | 270.5                           |
| 28650 00                | Cyclic crudes and intermediates,<br>n.s.k., for companies with 10<br>employees or more. (See note).               | 8.5                                                                | (X)                             | (X)                             | 11.9                                                               | (X)                             | (X)                             |
| 28650 02                | Cyclic crudes and intermediates<br>n.s.k., for companies with<br>less than 10 employees.<br>(See note).....       | 6.7                                                                | (X)                             | (X)                             | .8                                                                 | (X)                             | (X)                             |
| 2869- --                | INDUSTRIAL ORGANIC CHEMICALS,<br>N.E.C., TOTAL.....                                                               | 7,465.7                                                            | (X)                             | (X)                             | 5,539.4                                                            | (X)                             | (X)                             |
| 28691 11                | Miscellaneous cyclic (coal tar)<br>chemical products.....                                                         | 465.0                                                              | 417.0                           | 48.0                            | 315.1                                                              | 271.0                           | 44.1                            |
| 28692 13                | Miscellaneous acyclic chemicals<br>and chemical products, ex-<br>cluding urea <sup>2</sup> .....                  | 5,435.2                                                            | 4,107.4                         | 1,327.8                         | 4,052.2                                                            | 3,164.7                         | 887.5                           |
| 28693 --                | Synthetic organic chemicals,<br>N.E.C., except bulk surface<br>active agents.....                                 | 723.0                                                              | (X)                             | (X)                             | 585.6                                                              | (X)                             | (X)                             |
| 28693 11                | Flavor and perfume<br>materials.....                                                                              | 123.4                                                              | 116.3                           | 7.1                             | 119.0                                                              | (D)                             | (D)                             |
| 28693 31                | Rubber-processing chemicals <sup>1</sup>                                                                          | 228.2                                                              | 190.8                           | 37.4                            | 152.3                                                              | 137.1                           | 15.2                            |
| 28693 51                | Plasticizers <sup>1</sup> .....                                                                                   | 362.6                                                              | 306.5                           | 56.1                            | 309.2                                                              | 283.1                           | 26.1                            |
| 28693 00                | Synthetic organic chemicals,<br>n.e.c., n.s.k.....                                                                | 8.8                                                                | (X)                             | (X)                             | 5.1                                                                | (X)                             | (X)                             |
| 28694 11                | Pesticides and other synthetic<br>organic agricultural chemicals,<br>except preparations <sup>1</sup> .....       | 489.3                                                              | 434.1                           | 55.2                            | 308.2                                                              | 282.7                           | 25.5                            |
| 28695 --                | Ethyl alcohol and other in-<br>dustrial organic chemicals, n.e.c.<br>Ethyl alcohol <sup>3</sup> .....             | 280.3                                                              | (X)                             | (X)                             | 239.4                                                              | (X)                             | (X)                             |
| 28695 11                | Pure (natural).....                                                                                               | 35.0                                                               | (D)                             | (D)                             | 33.6                                                               | (D)                             | (D)                             |
| 28695 21                | Denatured (special or com-<br>plete), including natural<br>and synthetic for uses<br>other than rubbing.....      | 42.6                                                               | (D)                             | (D)                             | 44.2                                                               | (D)                             | (D)                             |
| 28695 31                | Flavor oil mixtures and blends..                                                                                  | 34.7                                                               | 34.7                            | -                               | 27.9                                                               | 27.9                            | -                               |
| 28695 37                | Reagent and high purity grades<br>of organic chemicals refined<br>from purchased technical<br>grades.....         | 23.0                                                               | 22.0                            | 1.0                             | 19.7                                                               | 19.7                            | -                               |
| 28695 51                | Natural organic chemicals,<br>n.e.c.....                                                                          | 60.4                                                               | (D)                             | (D)                             | 44.0                                                               | (D)                             | (D)                             |
| 28695 98                | Other industrial organic<br>chemicals.....                                                                        | 78.8                                                               | (D)                             | (D)                             | 67.8                                                               | 64.4                            | 3.4                             |
| 28695 00                | Other industrial organic<br>chemicals, n.s.k.....                                                                 | 5.6                                                                | (X)                             | (X)                             | 2.2                                                                | (X)                             | (X)                             |
| 28690 00                | Industrial organic chemicals,<br>n.e.c., n.s.k., for companies<br>with 10 employees or more.<br>(See note).....   | 58.2                                                               | (X)                             | (X)                             | 33.5                                                               | (X)                             | (X)                             |
| 28690 02                | Industrial organic chemicals,<br>n.e.c., n.s.k., for companies<br>with less than 10 employees.<br>(See note)..... | 14.7                                                               | (X)                             | (X)                             | 5.2                                                                | (X)                             | (X)                             |

Note: In the 1972 Census of Manufactures, shipments data for establishments of small companies, typically those with fewer than 10 employees, were estimated from administrative record data rather than collected from respondents. These shipments figures (which are further discussed in the text) are included in the code ending with "002." In both the 1972 and 1967 censuses of manufactures, products which were not completely identified on the standard forms were coded to the appropriate product-class code (5 digits) followed by "00," or in some cases to the appropriate product-group code (4 digits) followed by "000."

- Represents zero. (X) Not applicable. (D) Withheld to avoid disclosing figures for individual companies. (S) Withheld because the estimate did not meet publication standards either on the basis of the associated standard error of estimate or on the basis of a consistency review. (X) Less than half of the unit of measurement shown (less than 0.1 when rounded).

<sup>1</sup> Data for quantities produced and values shipped for many of the synthetic organic chemicals included in this grouping are shown in the U.S. Tariff Commission's Annual Report, "Synthetic Organic Chemicals, United States Production and Sales."

<sup>2</sup> 1967 and 1972 figures are not comparable. The 1967 totals for code 28692 13 include the values for urea. Due to revisions in the Standard Industrial Classification product classes, urea became code 28732 15 in 1972.

<sup>3</sup> For quantity information, refer to the U.S. Treasury Department, Internal Revenue Service publication: Alcohol and Tobacco-1972. Excludes shipments reported as rubbing alcohol (primary to industry 2834, Pharmaceutical Preparations), and as antifreeze (primary to industry 2899, Chemical Preparations, N.E.C.).

Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, "1972 Census of Manufactures", Industrial Organic Chemicals, SIC Industry Group 286.

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TABLE 4. MATERIALS CONSUMED, BY KIND: 1972

| 1972<br>code | Material                                                                                | INDUSTRY 2845--CYCLIC CHEMIS AND INTERMEDIATES |                    |                                                                  |                                        |                                                                   | INDUSTRY 2849--INDUSTRIAL ORGANIC CHEMICALS, N.E.C. |                    |                                                                  |                                        |                                                                   |
|--------------|-----------------------------------------------------------------------------------------|------------------------------------------------|--------------------|------------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------|--------------------|------------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------|
|              |                                                                                         | Total<br>consumption<br>(quantity)             | Unit of<br>measure | Materials<br>made and<br>consumed in<br>same plant<br>(quantity) | Basis                                  | Consumption of materials<br>received from other<br>establishments | Total<br>consumption<br>(quantity)                  | Unit of<br>measure | Materials<br>made and<br>consumed in<br>same plant<br>(quantity) | Basis                                  | Consumption of materials<br>received from other<br>establishments |
|              |                                                                                         |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
|              |                                                                                         |                                                |                    |                                                                  |                                        | Quantity                                                          | Delivered<br>cost<br>(million dollars)              |                    | Quantity                                                         | Delivered<br>cost<br>(million dollars) |                                                                   |
| 281944       | Materials, containers, and supplies,<br>total.....                                      | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | 945.8                                               | .....              | (X)                                                              | 3,436.5                                | (X)                                                               |
|              | Inorganic chemicals:                                                                    |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
|              | Acids, except spent acids:                                                              |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
|              | Hydrochloric acid.....                                                                  | 50.8                                           | 1,000 a.           | (X)                                                              | 100% HCl                               | 43.5                                                              | 2.8                                                 | .....              | 396.1                                                            | 14.8                                   | 928.4                                                             |
| 281946       | Hydrofluoric acid.....                                                                  | (X)                                            | tons.              | (X)                                                              | 100% HF                                | (X)                                                               | .....                                               | .....              | (D)                                                              | (D)                                    | (D)                                                               |
| 281948       | Nitric acid.....                                                                        | 589.5                                          | .....              | (X)                                                              | 100% HNO <sub>3</sub>                  | 101.4                                                             | 7.2                                                 | .....              | 221.2                                                            | 15.9                                   | 761.2                                                             |
| 281950       | Phosphoric acid.....                                                                    | (X)                                            | .....              | (X)                                                              | 100% H <sub>3</sub> PO <sub>4</sub>    | (X)                                                               | .....                                               | .....              | (D)                                                              | (D)                                    | (D)                                                               |
| 281952       | Sulfuric acid.....                                                                      | 800.7                                          | .....              | (X)                                                              | 100% H <sub>2</sub> SO <sub>4</sub>    | 331.0                                                             | 9.3                                                 | .....              | 1,202.1                                                          | 25.3                                   | 1,811.3                                                           |
| 281954       | Ammonia, synthetic, anhydrous.....                                                      | 191.9                                          | .....              | (X)                                                              | 100% NH <sub>3</sub>                   | 191.9                                                             | 7.4                                                 | .....              | 640.0                                                            | 25.4                                   | 863.1                                                             |
| 281956       | Chlorine.....                                                                           | (X)                                            | .....              | (X)                                                              | 100% Cl <sub>2</sub>                   | 331.8                                                             | 16.4                                                | .....              | 1,789.3                                                          | 76.4                                   | 5,114.3                                                           |
| 281958       | Phosphorus, elemental.....                                                              | (X)                                            | .....              | (X)                                                              | 100% P <sub>4</sub>                    | (X)                                                               | .....                                               | .....              | (D)                                                              | (D)                                    | (D)                                                               |
| 281960       | Sodium carbonate (soda ash).....                                                        | 42.0                                           | .....              | (X)                                                              | 50% Na <sub>2</sub> CO <sub>3</sub>    | 42.0                                                              | 2.2                                                 | .....              | 36.7                                                             | (D)                                    | (D)                                                               |
| 281962       | Sodium hydroxide (caustic soda).....                                                    | 476.3                                          | .....              | (X)                                                              | 100% NaOH                              | 476.3                                                             | 20.7                                                | .....              | 793.6                                                            | 38.3                                   | 949.3                                                             |
| 281964       | Organic chemicals:                                                                      |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
| 281966       | Alcohol, ethyl (pure and denatured).....                                                | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | 1.0                                                 | .....              | (X)                                                              | 39.8                                   | (X)                                                               |
| 281968       | Other alcohols, including methyl, butyl,<br>and isopropyl.....                          | 53.7                                           | .....              | (X)                                                              | .....                                  | 53.7                                                              | 9.3                                                 | .....              | 917.5                                                            | 122.4                                  | 217.9                                                             |
| 281970       | Acetone.....                                                                            | (X)                                            | .....              | (X)                                                              | 100% CH <sub>3</sub> CO                | (X)                                                               | .....                                               | .....              | 122.6                                                            | 15.9                                   | 375.6                                                             |
| 281972       | Benzaldehyde.....                                                                       | 77.1                                           | .....              | (X)                                                              | 100% C <sub>6</sub> H <sub>5</sub> CHO | 1,000.3                                                           | 35.2                                                | .....              | 2,793.0                                                          | 86.0                                   | 2,182.6                                                           |
| 281974       | Formaldehyde.....                                                                       | (X)                                            | .....              | (X)                                                              | 37% HCHO                               | 77.1                                                              | 2.2                                                 | .....              | 233.7                                                            | 5.2                                    | 6.4                                                               |
| 281976       | Liquefied petroleum and refinery gases<br>for chemical feedstocks:                      |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
| 281978       | Ethane.....                                                                             | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | 4,788.9                                                          | 134.9                                  | 6,487.0                                                           |
| 281980       | Propane.....                                                                            | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | 7,791.6                                                          | 26.2                                   | 1,800.1                                                           |
| 281982       | Butane.....                                                                             | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | 2,043.4                                                          | 56.4                                   | 375.6                                                             |
| 281984       | Propylene.....                                                                          | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | 1,462.4                                                          | 171.3                                  | (X)                                                               |
| 281986       | Other, including mixtures.....                                                          | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | 612.8                                                            | 27.8                                   | (X)                                                               |
| 281988       | Methane.....                                                                            | 213.5                                          | .....              | (X)                                                              | .....                                  | (X)                                                               | .....                                               | .....              | (X)                                                              | (X)                                    | (X)                                                               |
| 281990       | Benzene.....                                                                            | 438.9                                          | .....              | (X)                                                              | 100% C <sub>6</sub> H <sub>6</sub>     | 12.0                                                              | 3.4                                                 | .....              | 466.2                                                            | (X)                                    | (X)                                                               |
| 281992       | Phenol.....                                                                             | 61.9                                           | .....              | (X)                                                              | 100% C <sub>6</sub> H <sub>5</sub> OH  | 19.2                                                              | 1.8                                                 | .....              | 131.9                                                            | 11.2                                   | 291.8                                                             |
| 281994       | Nitrolic anhydride.....                                                                 | 19.2                                           | .....              | (X)                                                              | .....                                  | 19.2                                                              | 1.8                                                 | .....              | 443.7                                                            | (X)                                    | (X)                                                               |
| 281996       | Tar, crude.....                                                                         | (X)                                            | .....              | (X)                                                              | .....                                  | 1,299.5                                                           | 38.1                                                | .....              | (X)                                                              | (X)                                    | (X)                                                               |
| 281998       | Crude materials:                                                                        |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
| 282000       | Solid.....                                                                              | (X)                                            | 1,000 long<br>tons | (X)                                                              | .....                                  | 163.5                                                             | 4.4                                                 | .....              | 462.7                                                            | 13.1                                   | (X)                                                               |
| 282002       | Zinc and zinc-base alloy refinery shapes                                                | (X)                                            | 1,000 a.<br>tons   | (X)                                                              | .....                                  | .7                                                                | .3                                                  | .....              | (X)                                                              | (X)                                    | (X)                                                               |
| 282004       | Used as raw materials:                                                                  |                                                |                    |                                                                  |                                        |                                                                   |                                                     |                    |                                                                  |                                        |                                                                   |
| 282006       | Natural gas.....                                                                        | (X)                                            | .....              | (X)                                                              | .....                                  | 6,491.0                                                           | 3.0                                                 | .....              | 261,828.0                                                        | 64.8                                   | (X)                                                               |
| 282008       | Parts and attachments for chemical indus-<br>tries, machinery, and equipment.....       | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | 29.4                                                | .....              | (X)                                                              | 116.0                                  | (X)                                                               |
| 282010       | All other materials and components,<br>parts, containers, and supplies<br>consumed..... | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | 630.9                                               | .....              | (X)                                                              | 2,096.9                                | (X)                                                               |
| 282012       | Materials, containers, and supplies,<br>n.s.k. <sup>1</sup>                             | (X)                                            | .....              | (X)                                                              | .....                                  | (X)                                                               | 41.0                                                | .....              | (X)                                                              | 106.9                                  | (X)                                                               |

- Represents zero. (X) Not applicable. (NA) Not available. (D) Withheld to avoid disclosing figures for individual companies. (S) Withheld because the estimate did not meet publication standards, either on the basis of the associated standard error or on the basis of a consistency review. (Z) Less than half of the unit of measurement shown. (n.e.c.) Not elsewhere classified.

<sup>1</sup> This item represents the total cost of materials for establishments that did not report detailed materials data. It also includes estimates for companies that were not mailed report forms.

Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, "1972 Census of Manufacturers", Industrial Organic Chemicals, SIC Industry Group 286.



Although producing plants for industrial organic chemicals are scattered throughout several states, many are located near refineries which are located near domestic sources of oil or points of entry for imported oil. Some of the petrochemical plants border refineries, thus permitting an easy exchange of products. This results in a heavy concentration of chemical production along the Gulf coast and the east coast particularly in the area of New York, New Jersey and Pennsylvania. Additional concentrations occur along natural gas pipeline routes and water transportation arteries throughout the central United States and in the oil and gas fields of California. Significant organic chemical production occurs in some 30 states.

Table 5 presents general statistical data by geographical area for establishments classified in SIC codes 2865 and 2869. The tabulated entries reflect data for certain facilities and products which are outside the scope of this study, so the absolute value stated for any particular parameter must be considered high. Nevertheless, proportional relationships among the parameters and relative geographic/economic influence may be considered typical of the Industrial Organic Chemical Industry.

The industry has experienced a high growth rate almost since its beginning. U.S. production of industrial organic chemicals has increased over the years from an average of 16 Tg (35.3 billion pounds) during 1957 through 1959) to 25.7 Tg (60.0 billion pounds) in 1964, 47.3 Tg (104.3 billion pounds) in 1969 and 62.9 Tg (138.7 billion pounds) in 1974. However, the recent energy crisis has doubly affected the industry. Refined petroleum products and natural gas, traditional feedstocks for the production of the basic petrochemicals necessary to the industrial organic chemicals industry, are also

TABLE 5. INDUSTRIAL ORGANIC CHEMICALS: GENERAL STATISTICS BY GEOGRAPHICAL AREA

| Geographic Area                  | 2065-- CYCLIC CHAINS AND INTERMEDIATES |                           |                     |         |                            |                   |                   |                   |                    |                   | 2066-- INDUSTRIAL ORGANIC CHEMICALS, NEC |                           |               |         |                            |                   |                   |                   |                    |                   |                           |
|----------------------------------|----------------------------------------|---------------------------|---------------------|---------|----------------------------|-------------------|-------------------|-------------------|--------------------|-------------------|------------------------------------------|---------------------------|---------------|---------|----------------------------|-------------------|-------------------|-------------------|--------------------|-------------------|---------------------------|
|                                  | Establishments                         |                           | All employees       |         | Value added by manufacture |                   | Cost of materials |                   | Value of shipments |                   | Establishments                           |                           | All employees |         | Value added by manufacture |                   | Cost of materials |                   | Value of shipments |                   | Capital expenditures, new |
|                                  | Total                                  | With 20 employees or more | Number <sup>1</sup> | Payroll | (million dollars)          | (million dollars) | (million dollars) | (million dollars) | (million dollars)  | (million dollars) | Total                                    | With 20 employees or more | Number        | Payroll | (million dollars)          | (million dollars) | (million dollars) | (million dollars) | (million dollars)  | (million dollars) |                           |
| UNITED STATES.....               | 173                                    | 117                       | 24.2                | 317.6   | 925.2                      | 1 109.7           | 2 044.5           | 158.7             | 514                | 295               | 101.7                                    | 1 240.2                   | 316.5         | 725.4   | 4 965.1                    | 9 179.1           | 645.4             | (D)               | (D)                | (D)               |                           |
| NORTHEAST REGION.....            | 77                                     | 54                        | 13.9                | 152.7   | 383.1                      | 394.0             | 739.1             | (D)               | 176                | 98                | 27.1                                     | 316.5                     | 81.4          | 83.3    | 936.4                      | 1 670.0           | (D)               | (D)               | (D)                | (D)               |                           |
| NEW ENGLAND DIVISION.....        | 31                                     | 7                         | 1.2                 | 10.8    | 29.7                       | 28.4              | 60.5              | (D)               | 33                 | 15                | 5.8                                      | 61.4                      | 1.0           | 1.0     | 120.3                      | 212.3             | (D)               | (D)               | (D)                | (D)               |                           |
| MAINE.....                       | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 1                  | 1                 | AA                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| NEW HAMPSHIRE.....               | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 1                  | 1                 | AA                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| MASSACHUSETTS.....               | 7                                      | 4                         | BB                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 10                 | 2                 | CC                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| RHODE ISLAND.....                | 3                                      | 2                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 4                  | 2                 | CC                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| CONNECTICUT.....                 | 3                                      | 1                         | AA                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 17                 | 6                 | FF                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| MIDDLE ATLANTIC DIVISION.....    | 66                                     | 47                        | 12.7                | 141.9   | 333.4                      | 365.6             | 696.6             | (D)               | 141                | 83                | 21.4                                     | 255.0                     | 64.2          | 64.2    | 818.1                      | 1 457.7           | (D)               | (D)               | (D)                | (D)               |                           |
| NEW YORK.....                    | 12                                     | 6                         | 2.6                 | 29.4    | 48.1                       | 34.5              | 101.0             | (D)               | 38                 | 21                | 6.1                                      | 6.1                       | 6.1           | 35.6    | 158.6                      | 320.7             | (D)               | (D)               | (D)                | (D)               |                           |
| NEW JERSEY.....                  | 39                                     | 31                        | 8.3                 | 94.6    | 234.0                      | 245.8             | 485.1             | (D)               | 79                 | 44                | 13.1                                     | 169.6                     | 34.6          | 34.6    | 570.8                      | 1 015.6           | (D)               | (D)               | (D)                | (D)               |                           |
| PENNSYLVANIA.....                | 15                                     | 10                        | 1.8                 | 17.9    | 50.3                       | 62.3              | 112.4             | (D)               | 27                 | 13                | 2.2                                      | 21.3                      | 36.7          | 36.7    | 81.7                       | 121.4             | (D)               | (D)               | (D)                | (D)               |                           |
| NORTH CENTRAL REGION.....        | 33                                     | 22                        | 5.7                 | 65.4    | 166.1                      | 223.8             | 390.9             | (D)               | 103                | 51                | 15.1                                     | 182.3                     | 58.9          | 58.9    | 443.6                      | 1 016.2           | (D)               | (D)               | (D)                | (D)               |                           |
| EAST NORTH CENTRAL DIVISION..... | 29                                     | 21                        | FF                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 82                 | 45                | FF                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| OHIO.....                        | 16                                     | 10                        | EE                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 31                 | 19                | 3.1                                      | 35.6                      | 94.6          | 94.6    | 113.9                      | 215.0             | (D)               | (D)               | (D)                | (D)               |                           |
| INDIANA.....                     | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 5                  | 5                 | EE                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| ILLINOIS.....                    | 10                                     | 7                         | 2.6                 | 35.6    | 78.5                       | 104.7             | 187.6             | (D)               | 20                 | 6                 | CC                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| MICHIGAN.....                    | 3                                      | 3                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 17                 | 9                 | BB                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| WISCONSIN.....                   | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 9                  | 6                 | BB                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| WEST NORTH CENTRAL DIVISION..... | 4                                      | 1                         | AA                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 21                 | 6                 | EE                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| IOWA.....                        | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 3                  | 3                 | AA                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| MISSOURI.....                    | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 10                 | 3                 | EE                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| SOUTH REGION.....                | 52                                     | 38                        | 8.4                 | 97.1    | 390.0                      | 481.7             | 878.4             | 107.5             | 186                | 124               | 56.6                                     | 707.7                     | 3 326.4       | 3 326.4 | 2 702.0                    | 6 234.8           | 474.7             | (D)               | (D)                | (D)               |                           |
| SOUTH ATLANTIC DIVISION.....     | 24                                     | 18                        | 4.8                 | 53.1    | 169.9                      | 188.4             | 368.5             | 74.3              | 69                 | 41                | 13.7                                     | 149.4                     | 720.8         | 720.8   | 443.9                      | 1 164.8           | 44.4              | (D)               | (D)                | (D)               |                           |
| DELAWARE.....                    | 2                                      | 2                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | (NA)               | (NA)              | (NA)                                     | (NA)                      | (NA)          | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | (NA)               | (NA)              |                           |
| MARYLAND.....                    | 4                                      | 3                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | (NA)               | (NA)              | (NA)                                     | (NA)                      | (NA)          | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | (NA)               | (NA)              |                           |
| VIRGINIA.....                    | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 6                  | 3                 | EE                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| NORTH CAROLINA.....              | 5                                      | 4                         | EE                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 14                 | 12                | 9.4                                      | 108.3                     | 549.6         | 549.6   | 268.9                      | 822.7             | 30.2              | (D)               | (D)                | (D)               |                           |
| SOUTH CAROLINA.....              | 4                                      | 3                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 11                 | 7                 | CC                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| GEORGIA.....                     | 5                                      | 4                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 11                 | 7                 | CC                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| FLORIDA.....                     | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 7                  | 4                 | AA                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| EAST SOUTH CENTRAL DIVISION..... | 10                                     | 7                         | 1.4                 | 15.1    | 94.9                       | 88.8              | 185.6             | 7.3               | 30                 | 18                | 8.2                                      | 94.8                      | 311.4         | 311.4   | 358.4                      | 666.5             | 33.4              | (D)               | (D)                | (D)               |                           |
| KENTUCKY.....                    | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 8                  | 7                 | EE                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| TENNESSEE.....                   | 4                                      | 1                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 12                 | 6                 | FF                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| ALABAMA.....                     | 5                                      | 5                         | CC                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 5                  | 3                 | 4                                        | 4.9                       | 29.3          | 29.3    | 30.8                       | 57.9              | 8                 | (D)               | (D)                | (D)               |                           |
| WEST SOUTH CENTRAL DIVISION..... | 18                                     | 13                        | 2.2                 | 29.0    | 125.2                      | 204.6             | 324.4             | 25.9              | 87                 | 65                | 34.7                                     | 463.5                     | 2 494.2       | 2 494.2 | 1 899.6                    | 4 193.6           | 396.9             | (D)               | (D)                | (D)               |                           |
| LOUISIANA.....                   | 2                                      | 2                         | AA                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 26                 | 24                | FF                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| TEXAS.....                       | 16                                     | 11                        | EE                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 57                 | 39                | 23.9                                     | 318.3                     | 1 843.4       | 1 843.4 | 1 320.7                    | 3 161.4           | 251.9             | (D)               | (D)                | (D)               |                           |
| WEST REGION.....                 | 11                                     | 3                         | 2                   | 2.4     | 6.1                        | 10.2              | 16.1              | 9                 | 51                 | 22                | 2.9                                      | 35.8                      | 143.7         | 143.7   | 125.5                      | 268.1             | 19.8              | (D)               | (D)                | (D)               |                           |
| MOUNTAIN DIVISION.....           | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 5                  | 3                 | BB                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| COLORADO.....                    | (NA)                                   | (NA)                      | (NA)                | (NA)    | (NA)                       | (NA)              | (NA)              | (NA)              | 4                  | 2                 | AA                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |
| PACIFIC DIVISION.....            | 9                                      | 3                         | AA                  | (D)     | (D)                        | (D)               | (D)               | (D)               | 46                 | 19                | FF                                       | (D)                       | (D)           | (D)     | (D)                        | (D)               | (D)               | (D)               | (D)                | (D)               |                           |

Note: The payroll and sales data for small establishments (generally single-unit companies with less than 10 employees) were obtained from administrative records of other Government agencies instead of from sales tax reports. These data were then used in conjunction with industry averages to estimate the balance of the items shown in this table for the small establishments. This technique was also used for a small number of other establishments whose reports were not received at the time the data were tabulated. The following symbols are shown for those States where administrative records data were used and account for 10 percent or more of the figures shown:

E1--10 to 19 percent E3--30 to 39 percent E5--50 to 59 percent E7--70 to 79 percent E9--90 to 99 percent  
E2--20 to 29 percent E4--40 to 49 percent E6--60 to 69 percent E8--80 to 89 percent E0--100 percent

(NA) Not available. (D) Withheld to avoid disclosing figures for individual companies.

<sup>1</sup>General statistics for some producing areas are withheld to avoid disclosing figures for individual companies. However, for such areas with 150 employees or more, the number of establishments is shown and the employment size range is indicated by one of the following symbols:

AA--150 to 249 employees BB--250 to 499 employees CC--500 to 999 employees EE--1,000 to 2,499 employees FF--2,500 employees and over  
Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, "1972 Census of Manufacturers", Industrial Group 286.

the prime sources for the energy required by an industrialized nation as well as by chemical production facilities. With the demand placed on refinery products and natural gas for use as fuels, there is little economic incentive to increase production of refinery products and natural gas liquids to be used as petrochemical feedstocks. Thus, the industry has been affected not only by increased costs but also by feedstock shortages.

For this reason growth over the next several years is anticipated to be at a continuing slow rate and will probably be governed by improved production technology and energy conservation techniques. The continuity of feedstock supply is almost more important than feedstock price. As a result the industry has been under considerable pressure to acquire its own sources of raw material. The need for such backward integration could lead not only to the acquisition of basic petrochemical production facilities but even to the acquisition of sources of raw materials for these and finally to control of the well or mine.

Table 6 presents data for fuels and electrical energy consumed by establishments classified in SIC codes 2865 and 2869 during 1971. Specific data relating to only those companies producing industrial organic chemicals as defined herein were not found in the sources consulted for this study. The tabulation indicates that some on-site generation of electrical energy occurred at facilities classified under these codes, but quantitative data were not available.

#### Raw Materials

The raw materials for the industry consist primarily of the products of the Basic Petrochemicals Industry. Thus, any adverse environmental impact

Table 6. FUELS AND ELECTRIC ENERGY CONSUMED IN 1971 BY  
COMPANIES IN SIC CODES 2865 AND 2869

|                                      | SIC 2865                                                       | SIC 2869                                                         |
|--------------------------------------|----------------------------------------------------------------|------------------------------------------------------------------|
| Coal                                 | (497,000 s tons) 450.8 Gg                                      | (5,036,600 s tons) 4,569 Tg                                      |
| Distillate and Residual Fuel Oil     | (4,748,100 bbl) 754.3 dam <sup>3</sup>                         | (4,358,000 bbl) 692.4 dam <sup>3</sup>                           |
| Natural Gas                          | (69.4 x 10 <sup>9</sup> ft <sup>3</sup> ) 1.97 km <sup>3</sup> | (586.1 x 10 <sup>9</sup> ft <sup>3</sup> ) 16.59 km <sup>3</sup> |
| Purchase Electric Energy             | 3.324 TWh                                                      | 19.7 TWh                                                         |
| Total Energy Used for Heat and Power | 40.3 TWh equiv.                                                | 286.0 TWh equiv.                                                 |

Source: U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of Census, "1972 Census of Manufactures", Industrial Organic Chemicals, SIC Industry Group 286.

associated with the production of raw materials for this industry is that associated with production, transfer, and interim storage of olefins, aromatics, and paraffins. Hydrocarbon emissions during raw material production are estimated to range from 0.1 to 0.6 percent of plant throughput. Non-hydrocarbon pollutants include water treatment wastes, products from sulfur and nitrogen removal processes, combustion and incineration products, catalyst cleaning waste, spent catalysts and solid absorbents. For a more complete examination of pollutant and potential pollutant generation from raw materials production, the reader is referred to Chapter 5.

As noted above, the primary raw materials for this industry are olefins, aromatics and paraffins. Olefins are characterized by a highly reactive double bond which renders them extremely useful in a variety of syntheses. Ethylene surpasses all other hydrocarbons both in production volume and in diversity of commercial use. Ethylene production has grown from 136 Gg (300 million pounds) in 1940 to 2.27 Tg (5 billion pounds) in 1960 and to over 8.16 Tg (18 billion pounds) in 1970. Propylene, though not produced in as great a quantity as ethylene, is also an important raw material for this industry. In 1969, about 3.87 Tg (8.5 billion pounds) of propylene was consumed to make chemicals.

Benzene is the most important aromatic, second only to ethylene as a building block for synthetic organic chemicals. Figures for total consumption of benzene by the industry are not available. Data published in the 1972 Census of Manufacturers for those establishments classified in SIC code 2869 indicate a benzene consumption of 1.44 Tg (3.17 billion pounds). Toluenes and mixed xylenes are likewise important feedstock materials, though not on



a level with benzene. Napthalene and cresols comprise the balance of the significant aromatic feedstocks to this industry.

The paraffins, or alkanes, are saturated hydrocarbons. Methane,  $\text{CH}_4$ , is the simplest member of this class, with subsequent members differing by multiples of one carbon and two hydrogen atoms. Paraffins containing one to four carbons are gases at standard temperature and pressure, while those containing five or more carbons are liquids or solids. Paraffins are the least reactive of the hydrocarbons and all of the common processing methods require elevated temperature and pressures. Paraffins with four or more carbons can exist in branched-chain forms, the number of possible isomers increasing with the number of carbon atoms. The principal paraffin feedstocks used by the industry are one- to five-carbon molecules.

Toxicity ratings for selected hydrocarbons used as industry feedstocks are shown in Table 7. A complete list of raw materials used in the production of the chemicals treated in this chapter is contained in Appendix B. Chemicals which are listed as raw materials but which are also themselves products of the industry and for which process descriptions are included in this chapter are identified with an asterisk. Materials which function as catalysts are listed in Appendix C.

### Products

Process descriptions for some 442 industrial organic chemicals are included in this study. These chemicals are used as solvents or chemical intermediates by downstream industries to produce organic chemical products estimated by one source to number from 8,000 to 10,000. During 1974 nearly 64 Tg (139 billion pounds) of cyclic and acyclic chemicals and chemical intermediates



Table 7. TOXICITY OF SELECTED FEEDSTOCKS FOR THE INDUSTRIAL  
ORGANIC CHEMICALS INDUSTRY

|            |                                                                                                                                                                      |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ethylene   | Low toxicity.                                                                                                                                                        |
| propylene  | Low toxicity.                                                                                                                                                        |
| butylene   | Butene-1, <u>cis</u> -butene-2, and <u>trans</u> -butene-2 isomers are asphyxiant gases; isobutene isomer is non-toxic.                                              |
| benzene    | Highly toxic by ingestion, inhalation and skin absorption; tolerance 25 ppm in air.                                                                                  |
| toluene    | Moderately toxic by ingestion, inhalation and skin absorption; tolerance 200 ppm in air.                                                                             |
| xylene     | Moderately toxic by ingestion or inhalation; tolerance 100 ppm in air.                                                                                               |
| napthalene | Moderately toxic; tolerance 10 ppm in air.                                                                                                                           |
| cresols    | Moderate to highly toxic irritant; corrosive to skin and mucous membranes; absorbed through skin; tolerance 5 ppm in air; 22 mg/m <sup>3</sup> in air; low toxicity. |
| ethane     | Not available.                                                                                                                                                       |
| propane    | Non-toxic.                                                                                                                                                           |
| butane     | Asphyxiant gas.                                                                                                                                                      |
| n-pentane  | Tolerance 500 ppm in air.                                                                                                                                            |
| isopentane | Low toxicity.                                                                                                                                                        |

Source: Hawley, Gessner, G. Condensed Chemical Dictionary. 8th Ed. N.Y., Van Nostrand-Reinhold, 1971.

with a value of approximately 7 billion dollars were produced in the United States. In general, the products of the Industrial Organic Chemical Industry are used as feedstock to such downstream industries as adhesives; agricultural chemicals; automotive chemicals; dyes; elastomers; explosives; paints and protective coatings; refrigerants and propellant gases; petroleum production and processing; pharmaceuticals, plastics, resins and synthetic fibers; solvents; surfactants; and others, including the chemical manufacturing industry itself. Because of the number of processing steps from feedstock to end-product, intra-industry sales reach significant levels.

Table 8 lists the 25 organic chemicals with the highest production volume in 1973. The chemicals listed accounted for 62.6 percent of the total production of this industry for 1973. Eighteen of the 25 chemicals listed find direct application in the plastics, plasticizers and fibers industries. Nine of the chemicals are used directly in the preparation of solvents and as intermediates in the production of other organic chemicals. Eight of the chemicals find direct application in manufacturing of agricultural chemicals, seven each in the preparation of dyes, pharmaceuticals, and paints or other protective coatings. Twelve of the chemicals listed are used as primary or alternate feedstocks for the production of other members of the list.

A list of the 25 organic chemicals with the highest market value is presented in Table 9. Tetraalkyl lead compounds exclusive of tetraethyl lead, for which no sales data were available, accounted for over 7.2 percent of the total chemical sales in 1973 as reported to the U.S. International Trade Commission. During 1974 domestic consumption of these compounds dropped by 12.4 percent. The relative economic importance of tetraalkyl lead compounds can be expected to diminish still further, as automotive gas line

Table 8. THE MOST SIGNIFICANT SYNTHETIC ORGANIC CHEMICALS  
BY PRODUCTION VOLUME IN 1973

| Chemical                     | Production<br>Gg | Sales Volume<br>Gg | Market Value<br>\$1000 |
|------------------------------|------------------|--------------------|------------------------|
| Ethylene dichloride          | 4215             | 613.0              | 40,489                 |
| Urea                         | 3214             | 3065               | 228,103                |
| Methanol                     | 3204             | 1743               | 64,306                 |
| Formaldehyde (37% by weight) | 2914             | 1257               | 51,578                 |
| Styrene                      | 2710             | 1288               | 199,141                |
| Ethylbenzene                 | 2580             | 188.3              | 20,873                 |
| Vinyl chloride               | 2427             | 1612               | 147,518                |
| Ethylene oxide               | 1890             | 231.4              | 34,913                 |
| Ethylene glycol              | 1487             | 1283               | 193,317                |
| Cumene                       | 1209             | 635.4              | 52,510                 |
| Dimethyl terephthalate       | 1163             | 594.9              | 165,875                |
| Acetic acid                  | 1102             | 276.1              | 32,069                 |
| p-Xylene                     | 1055             | 711.8              | 100,635                |
| Phenol                       | 1032             | 595.2              | 100,508                |
| Cyclohexane                  | 962.8            | 900.2              | 89,860                 |
| Acetone                      | 902.4            | 702.0              | 67,928                 |
| Ethyl alcohol                | 889.9            | 689.6              | 84,015                 |
| Isopropyl alcohol            | 832.3            | 408.1              | 52,533                 |
| Propylene oxide              | 795.2            | NA                 | NA                     |
| Acetic anhydride             | 757.5            | NA                 | NA                     |
| Adipic acid                  | 710.8            | 69.28              | 24,757                 |
| Vinyl acetate                | 681.6            | 436.7              | 67,095                 |
| Acrylonitrile                | 614.2            | 218.0              | 50,878                 |
| o-Xylene                     | 484.4            | 351.5              | 37,998                 |
| Carbon tetrachloride         | 475.1            | 448.8              | 59,531                 |

NA - Indicates data not available.

Source: U.S. International Trade Commission. Synthetic Organic Chemicals, United States Production and Sales, 1973. ITC Publication 728. Washington, GPO, 1975.

Table 9. THE MOST SIGNIFICANT SYNTHETIC ORGANIC CHEMICALS  
BY MARKET VALUE IN 1973

| Chemical                                          | Production<br>Gg | Sales Volume<br>Gg | Market Value<br>\$1000 |
|---------------------------------------------------|------------------|--------------------|------------------------|
| Tetraalkyl lead compounds*                        | 346.3            | 435.0              | 518,667                |
| Urea                                              | 3214             | 3065               | 228,103                |
| Styrene                                           | 2710             | 1288               | 199,141                |
| Ethylene glycol                                   | 1487             | 1283               | 193,317                |
| Dimethyl terephthalate                            | 1163             | 594.9              | 165,875                |
| Vinyl chloride                                    | 2427             | 1612               | 147,518                |
| Toluene-2,4- and .2,6-diisocyanate<br>(80/20 mix) | 229.5            | 198.8              | 126,261                |
| Dichlorodifluoromethane                           | 221.7            | 210.4              | 110,812                |
| p-Xylene                                          | 1055             | 711.8              | 110,635                |
| Phenol                                            | 1032             | 595.2              | 100,508                |
| Cyclohexane                                       | 962.8            | 900.2              | 89,680                 |
| Ethyl alcohol                                     | 889.9            | 689.6              | 84,015                 |
| Acetone                                           | 902.4            | 702.0              | 67,928                 |
| Vinyl acetate                                     | 681.6            | 436.7              | 67,095                 |
| Methanol                                          | 3204             | 1743               | 64,306                 |
| Trichlorofluoromethane                            | 151.4            | 149.2              | 61,352                 |
| Phthalic anhydride                                | 463.8            | 290.8              | 61,326                 |
| Polymethylene polyphenylisocyanate                | 128.0            | 101.4              | 59,536                 |
| Carbon tetrachloride                              | 475.1            | 448.8              | 59,531                 |
| Caprolactam                                       | 297.7            | 133.3              | 57,944                 |
| Isopropyl alcohol                                 | 832.3            | 408.1              | 52,533                 |
| Cumene                                            | 1209             | 635.4              | 52,510                 |
| Formaldehyde (37% by weight)                      | 2194             | 1257               | 51,578                 |
| Acrylonitrile                                     | 614.2            | 218.0              | 50,878                 |
| 1,1,1-Trichloroethane                             | 248.7            | 256.8              | 49,534                 |

\*Exclusive of tetraethyl lead

Source: U.S. International Trade Commission. Synthetic Organic Chemicals, United States Production and Sales, 1973. ITC Publication 728. Washington, GPO, 1975.

producers shift to a higher percentage output of unleaded products in order to service the increasing population of vehicles requiring such fuel.

Dichlorodifluoromethane, trichlorofluoromethane, and 1,1,1-trichloroethane accounted for over 3 percent of total reported chemical sales in 1973. Production and sales volume of these halocarbons can be expected to diminish somewhat as a result of concern over the theoretically adverse effect of halocarbons on atmospheric ozone.

Four of the listed chemicals, toluene-2,4- and 2,6-diisocyanate, phthalic anhydride, polymethylene polyphenylisocyanate and caprolactam, are used primarily in the production of plastics and synthetic fibers and collectively accounted for 4.25 percent of total chemical sales during 1973. Seventeen of the chemicals listed in Table 9 appear also in Table 8. The chemicals listed in Table 9, in aggregate, accounted for 39.4 percent of the total market value of industrial organic chemical sales in 1973. Appendix D lists 358 organic chemicals considered significant to the industry by reason of production volume, economic impact, environmental impact or toxicity factors.

#### Companies

The bulk of the output of industrial organic chemicals is contributed by large multi-line chemical companies and by chemical divisions or subsidiaries of the major oil companies. Many of these are multi-national organizations, some being headquartered outside the United States. A list of the leading chemical companies operating in the United States during 1973 is presented in Table 10. The companies listed are all producers of industrial organic chemicals. However, the tabulated sales figures also include sales of basic petrochemicals as well as downstream industrial products including plastics

TABLE 10. LEADING CHEMICAL COMPANIES IN THE U.S. DURING 1973

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|                                                                   | CHEMICAL SALES<br>\$ MILLIONS |        |        | TOTAL SALES<br>\$ MILLION |          |          |
|-------------------------------------------------------------------|-------------------------------|--------|--------|---------------------------|----------|----------|
|                                                                   | 1973                          | 1972   | 1971   | 1973                      | 1972     | 1971     |
| Du Pont                                                           | \$4250                        | \$3550 | \$2950 | \$ 5,276                  | \$ 4,366 | \$ 3,848 |
| Union Carbide                                                     | 2400                          | 1960   | 1884   | 3,939                     | 3,261    | 3,038    |
| Monsanto                                                          | 2355                          | 1924   | 1776   | 2,648                     | 2,225    | 2,087    |
| Dow Chemical                                                      | 2250                          | 1800   | 1550   | 3,068                     | 2,404    | 2,053    |
| Exxon                                                             | 1563                          | 1258   | 1077   | 25,724                    | 20,310   | 18,701   |
| Celanese                                                          | 1508                          | 1279   | 1131   | 1,609                     | 1,385    | 1,236    |
| W. R. Grace <sup>a</sup>                                          | 1317                          | 1088   | 974    | 2,808                     | 2,315    | 2,049    |
| Allied Chemical                                                   | 1114                          | 1001   | 892    | 1,665                     | 1,501    | 1,326    |
| Occidental Petroleum                                              | 1080                          | 831    | 705    | 3,456                     | 2,721    | 2,635    |
| Hercules                                                          | 1000                          | 795    | 678    | 1,155                     | 932      | 812      |
| Eastman Kodak                                                     | 792                           | 694    | 612    | 4,036                     | 3,478    | 2,976    |
| Rohm and Haas                                                     | 750                           | 588    | 482    | 789                       | 619      | 507      |
| Shell Oil                                                         | 748                           | 645    | 556    | 4,884                     | 4,076    | 3,892    |
| PMC                                                               | 745                           | 657    | 646    | 1,719                     | 1,498    | 1,354    |
| American Cyanamid                                                 | 708                           | 644    | 600    | 1,472                     | 1,359    | 1,283    |
| Phillips Petroleum                                                | 697                           | 490    | 408    | 2,990                     | 2,513    | 2,363    |
| Borden                                                            | 690                           | 515    | 450    | 2,554                     | 2,193    | 2,070    |
| Stauffer Chemical                                                 | 621                           | 543    | 493    | 621                       | 543      | 493      |
| Mobil Oil                                                         | 570                           | 470    | 420    | 11,390                    | 9,166    | 8,243    |
| Standard Oil(Ind.)                                                | 510                           | 410    | 341    | 5,416                     | 4,503    | 4,054    |
| Ethyl Corp. <sup>a</sup>                                          | 499                           | 458    | 416    | 699                       | 632      | 577      |
| Akzona                                                            | 485                           | 391    | 351    | 704                       | 572      | 506      |
| Texaco                                                            | 480                           | 400    | 350    | 11,407                    | 8,693    | 7,529    |
| Gulf Oil                                                          | 455                           | 363    | 300    | 8,417                     | 6,243    | 5,940    |
| Diamond Shamrock                                                  | 454                           | 404    | 368    | 651                       | 617      | 573      |
| B. F. Goodrich <sup>a</sup>                                       | 452                           | 363    | 286    | 1,661                     | 1,507    | 1,237    |
| PPG Industries                                                    | 440                           | 405    | 359    | 1,513                     | 1,396    | 1,238    |
| Ashland Oil <sup>a</sup>                                          | 427                           | 352    | 327    | 2,053                     | 1,780    | 1,635    |
| Standard Oil of California (Includes<br>Chevron Chemical Company) | 422                           | 304    | 277    | 7,762                     | 5,829    | 5,143    |
| U.S. Steel                                                        | 394                           | 310    | 298    | 6,952                     | 5,429    | 4,963    |
| Air Products <sup>a, b</sup>                                      | 388                           | 342    | 297    | 399                       | 351      | 308      |
| Ciba-Geigy                                                        | 380                           | 350    | 380    | 550                       | 500      | 550      |
| Olin                                                              | 370                           | 329    | 281    | 1,239                     | 1,098    | 1,145    |
| Cities Service <sup>a</sup>                                       | 367                           | 424    | 391    | 2,035                     | 1,862    | 1,810    |
| BASF Wyandotte                                                    | 356                           | 299    | 254    | 378                       | 316      | 254      |
| Mobay (Formerly Baychem)                                          | 333                           | 263    | 209    | 333                       | 263      | 209      |
| Goodyear Tire                                                     | 325                           | 250    | 236    | 4,675                     | 4,072    | 3,602    |
| William Cos.                                                      | 312                           | 205    | 50     | 744                       | 578      | 412      |
| El Paso Natural Gas                                               | 301                           | 254    | 271    | 983                       | 1,097    | 1,037    |
| Tenneco                                                           | 299                           | 277    | 254    | 3,910                     | 3,275    | 2,841    |
| Richnold Chemicals                                                | 294                           | 217    | 194    | 294                       | 217      | 194      |
| Merck                                                             | 280                           | 235    | 210    | 1,115                     | 958      | 829      |
| Pfizer <sup>a</sup>                                               | 279                           | 222    | 204    | 1,284                     | 1,093    | 952      |
| Lubrizol                                                          | 274                           | 217    | 198    | 274                       | 217      | 198      |
| Borg-Warner <sup>a</sup>                                          | 264                           | 201    | 165    | 1,547                     | 1,283    | 1,148    |
| Airco <sup>b</sup>                                                | 262                           | 240    | 192    | 584                       | 492      | 441      |
| American Hoechst                                                  | 260                           | 220    | 200    | 339                       | 260      | 235      |
| Chemtron                                                          | 249                           | 224    | 224    | 353                       | 314      | 276      |
| Pennwalt                                                          | 246                           | 199    | 183    | 504                       | 441      | 406      |

(a) Significant nonchemical sales (welding and cryogenic equipment, fabricated plastics products, coatings, metals, textiles, and the like) included with the chemical sales. (b) For fiscal year ended Sept. 30. (na = not available).

Source: Chemical and Engineering News, June 3, 1974.



and resins, dyes, plasticizers and agricultural chemicals. In addition, as noted in the table, the sales figures may include significant nonchemical sales. Nevertheless, the relationship between tabulated data for chemical sales and total sales during 1971 through 1973 is indicative of the degree of specialization as chemical producers.

In addition to the companies listed, there are hundreds of smaller companies specializing in a limited line of intermediate or end-product chemicals. In general, sales and profits are commensurate with the limited product line.

A number of factors account for the dominance of this industry by large multi-line and multi-national companies. Among these are:

- 1) Substantial costs for product and process research and development,
- 2) High plant investment in order to affect reduced product prices through large scale production techniques,
- 3) Competition for world supplies of raw materials,
- 4) Necessity of an extensive product line (horizontal integration) in order to provide a broad economic base for the company,
- 5) Economic advantages realized by integration of basic operations common to the production of a number of different end products, and
- 6) Ability to compete in the world market and to take advantage of world wide supply and demand fluctuation.

Traditionally, the industrial organic chemicals industry has relied heavily upon horizontal integration to assure some level of economic stability. In recent years, however, the main influence has been the need for vertical integration. Firms that until recently were secure in the production of

intermediates or of end-products have been under pressure either to integrate backward, by acquiring their own sources of raw materials, or to integrate forward by gaining control of client industries.

Thus, it may be expected that the more highly capitalized chemical companies are better equipped for such vertical integration and can be expected to maintain their present dominance of the industry. Most have already enlarged the scope of their activities, both by diverse acquisition and by internal expansion, and have advanced their position in the market at the expense of companies which have maintained an original structure.

A list of 260 companies involved in the production of industrial organic chemicals at 544 sites is presented in Appendix E.

#### Environmental Impacts

Hydrocarbons are major constituents of the gaseous emissions from industrial organic chemical plants. Hydrocarbons may be emitted to the atmosphere in a number of ways. Vent gases from various process operations may contain hydrocarbons, and large quantities of hydrocarbon carrying gases may sometimes be vented as a result of upset conditions in a plant or by the passage of gases through safety valves or relief vents. Leaks in vessels, pump seals, and pipe walls are also a source of fugitive hydrocarbon emissions. Reaction or process air required for a number of organic chemical manufacturing processes can be a source of significant hydrocarbon emissions. Some examples of air requirements for processes are: (1) for synthesis gas, every ton of product requires 4 tons of the air; (2) the production of hydrogen cyanide requires 10 tons of air per ton of product; and (3) acetic anhydride requires 5 tons of air per ton of product. Feedstock shortages stemming from the

current energy crisis have caused the industry to expand efforts in developing technology for increased product recovery. This, combined with more effective recovery and recycling of reagent materials, should lead to a significant decrease in atmospheric emissions from the chemical industry.

While air pollution constitutes a problem for manufacturers of organic chemicals, its magnitude does not compare with that posed by industrial water pollution. The sources of liquid waste streams can be divided into five general categories: (1) waste containing a principal raw material or product resulting from the stripping of the product from solution; (2) by-products produced during reactions; (3) spills, slab wash-downs, vessel cleanouts, sample overflows, etc; (4) cooling tower and boiler blowdown, steam condensate, water treatment waste, and general wash water; and (5) storm waters, for which the degree of contamination depends on the nature of the drainage area. The principal contaminants in the wastewaters include organics from residual products and by-products, oils from the bottom of distillation and stripping columns, suspended solids, and catalysts. Many of the compounds present in the effluents from typical processes are indicated in Table 11.

Numerous solvent processes are utilized in the purification of chemical feedstocks, intermediates, and products used and manufactured by the organic chemicals industry. Since the solvents used are expensive, recovery and recycle operations are usually employed. Therefore, it is doubtful that large quantities will be found in waste streams. Nevertheless, even low concentrations of many of the solvents used by the industry have possible carcinogenic or other biological effects.

Table 11. INDUSTRIAL ORGANIC CHEMICAL PROCESSES AS WASTE SOURCES

| Process                                                                | Source                                      | Pollutants                                                                                                              |
|------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Alkylation:<br>Ethylbenzene                                            |                                             | Tar, hydrochloric acid, caustic soda, fuel oil                                                                          |
| Cyanide production                                                     | Water slops                                 | Hydrogen cyanide, unreacted soluble hydrocarbons                                                                        |
| Dehydrogenation:<br>Butadiene product<br>from n-Butane and<br>Butylene | Quench waters                               | Residue gas, tars, oils, soluble hydrocarbons                                                                           |
| Ketone production                                                      | Distillation slops                          | Hydrocarbon polymers, chlorinated hydrocarbons,<br>glycerol, sodium chloride                                            |
| Styrene from<br>ethylbenzene                                           | Catalyst<br>Condensates from<br>spray tower | Spent catalyst (Fe, Mg, K, Cu, Cr, Zn)<br>Aromatic hydrocarbons, including styrene, ethyl<br>benzene, and toluene, tars |
| Extraction and<br>purification:<br>Isobutylene                         | Acid and caustic<br>wastes                  | Sulfuric acid, C <sub>4</sub> hydrocarbon, caustic soda                                                                 |
| Butylene                                                               | Solvent and caustic<br>wash                 | Acetone, oils, C <sub>4</sub> hydrocarbon, caustic soda,<br>sulfuric acid                                               |
| Styrene                                                                | Still bottoms                               | Heavy tars                                                                                                              |
| Butadiene                                                              | Solvent                                     | Cuprous ammonium acetate, C <sub>4</sub> hydrocarbons,<br>oils                                                          |
| Extractive<br>distillation                                             | Solvent                                     | Furfural, C <sub>4</sub> hydrocarbons                                                                                   |
| Halogenation<br>(principally<br>chlorination)                          |                                             |                                                                                                                         |
| Addition to<br>olefins                                                 | Separator                                   | Spent caustic                                                                                                           |

Table 11. INDUSTRIAL ORGANIC CHEMICAL PROCESSES AS WASTE SOURCES

| Process                                                     | Source                    | Pollutants                                                                                           |
|-------------------------------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------|
| Halogenation:<br>(continued)                                |                           |                                                                                                      |
| Substitution                                                | HCl absorber,<br>scrubber | Chlorine, hydrogen chloride, spent caustic,<br>hydrocarbon isomers and chlorinated products,<br>oils |
|                                                             | Dehydrohalogenation       | Dilute salt solution                                                                                 |
| Hypochlorination                                            | Hydrolysis                | Calcium chloride, soluble organics, tars                                                             |
| Hydrochlorination                                           | Surge tank                | Tars, spent catalyst, alkyl halides                                                                  |
| Hydrocarboxylation<br>(OXO Process)                         | Still slops               | Soluble hydrocarbons, aldehydes                                                                      |
| Hydrocyanation (for<br>acrylonitrile,<br>adipic acid, etc.) | Process effluents         | Cyanides, organic and inorganic                                                                      |
| Isomerization in<br>general                                 | Process wastes            | Hydrocarbons; aliphatic, aromatic, and<br>derivative tars                                            |
| Nitration<br>Paraffins                                      |                           | Byproduct aldehydes, ketones, acids, alcohols<br>olefins, carbon dioxide                             |
| Aromatics                                                   |                           | Sulfuric acid, nitric acid, aromatics                                                                |
| Oxidation<br>Ethylene oxide<br>and glycol mfg.              | Process slops             | Calcium chloride, spent lime, hydrocarbon<br>polymers, ethylene oxide, glycols, dichloride           |
| Aldehydes,<br>alcohols, and<br>acids from<br>hydrocarbons   | Process slops             | Acetone, formaldehyde, acetaldehyde, methanol,<br>higher alcohols, organic acids                     |



Table 11. INDUSTRIAL ORGANIC CHEMICAL PROCESSES AS WASTE SOURCES

| Process                                   | Source                                                          | Pollutants                                                                                                                                                    |
|-------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Oxidation (Cont.)                         |                                                                 |                                                                                                                                                               |
| Acids, anhydrides from aromatic oxidation | Condensates<br>Still slops                                      | Anhydrides, aromatics, acids<br>Pitch                                                                                                                         |
| Phenol, acetone from aromatic oxidation   | Decanter                                                        | Formic acid, hydrocarbons                                                                                                                                     |
| Sulfation of olefins                      |                                                                 | Alcohols, polymerized hydrocarbons, sodium sulfate, ethers                                                                                                    |
| Sulfonation of aromatics                  | Caustic wash                                                    | Spent caustic                                                                                                                                                 |
| Utilities                                 | Boiler blow-down<br>Cooling system blow-down<br>Water treatment | Phosphates, lignins, heat, total dissolved solids, tannins<br>Chromates, phosphates, algicides, heat<br>Calcium and magnesium chlorides, sulfates, carbonates |



Caustic washes utilizing aqueous sodium hydroxide solutions are frequently used. Sodium hydroxide solutions are used to extract from process streams various acidic contaminants such as hydrogen sulfide, mercaptans, phenols, biphenyls, and organic acids. Most spent caustic streams can therefore be expected to contain some or all of these compounds in the form of sodium salts as well as some unreacted sodium hydroxide, small quantities of the process product, and feed chemicals. Caustic washes are also used to recover unreacted acidic chemicals in such processes as chlorination, sulfation, sulfonation, polymerization, or oxidation.

Organic chemical processing also involves the use of various acid washes to remove basic materials from product streams. Acidic washes are often used also in removing contaminants from various phenolic product streams. Acid process effluents also are present in some operations, notably alkylation processes.

Caustic or acid washing is often followed by a clear water rinse to remove traces of the washing compounds. Off-gases from various units also are scrubbed with water to remove contaminants. Effluent waters usually will contain pollutants similar in nature to those found in the preceding spent caustic or acid washes, but at significantly lower concentration levels.

Other possible processing operations which may contribute pollutants include spillage of organic chemicals during transport or storage operations and run-off from processing areas. Spent catalyst material may be a component of aqueous waste streams and often can be a serious pollutant in terms of biological toxicity, even though it may be present only in small quantities.

The major solid waste from organic chemical processing is usually associated with bottoms from process tanks, from distillation and stripping columns, and in wastes from the cleaning of storage tanks. This material is usually in the form of a sludge which contains unreacted raw chemicals or products and spent catalysts. These sludges are usually disposed of either by incineration or by landfill.

Specific information relating to pollutants and abatement procedures, when available, is included in the process descriptions.

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INDUSTRY ANALYSIS

## INDUSTRY ANALYSIS

The Industrial Organic Chemicals Industry is discussed in terms of ten feedstock groups: benzene, butylenes, sources of cresylic acids, ethylene, methane, naphthalene, paraffins, propylene, toluene and xylenes. In an effort to complete this study within the imposed time limitations process descriptions vary from very detailed to somewhat general. This is an extremely complex industry and the prescribed brevity of process descriptions has, no doubt, led to process oversimplifications in many cases.

Each feedstock group is discussed in terms of a chemical tree--giving an overview of the products and processing steps described; a process flow sheet--giving a synopsis of the reaction steps involved in the generation of a product and the more important input and output materials for each reaction step; and a concise process description. Examination of the various feedstock chemical trees and process flow sheets will reveal that many products could have come from more than one feedstock group and that many more products could not have been generated without the use of products of the other feedstock groups.

Data are given in metric units according to the System Internationale described in the ASTM Metric Practice Guide.

For each process description an attempt was made to present data first from a recognized authoritative source [e.g., Kirk-Othmer, "Encyclopedia of Chemical Technology"; Lowenheim and Moran, "Industrial Chemicals," 4th Ed. (1975)] and, if not available there then from various specialized publications. The recognized deficiencies in the data prepared for this chapter exist in the general lack of information on waste streams and to a somewhat lesser extent on utilities. For those processes for which no waste



stream information could be found in the literature best professional judgement was used to indicate possible pollutants. Another general characteristic of the Industrial Organic Chemicals Industry is that there appears to be a continuing change in processes for many of the products generated. Thus, this should be at least one of the industrial segments that should require a periodic update.

SECTION I  
BENZENE

# BENZENE

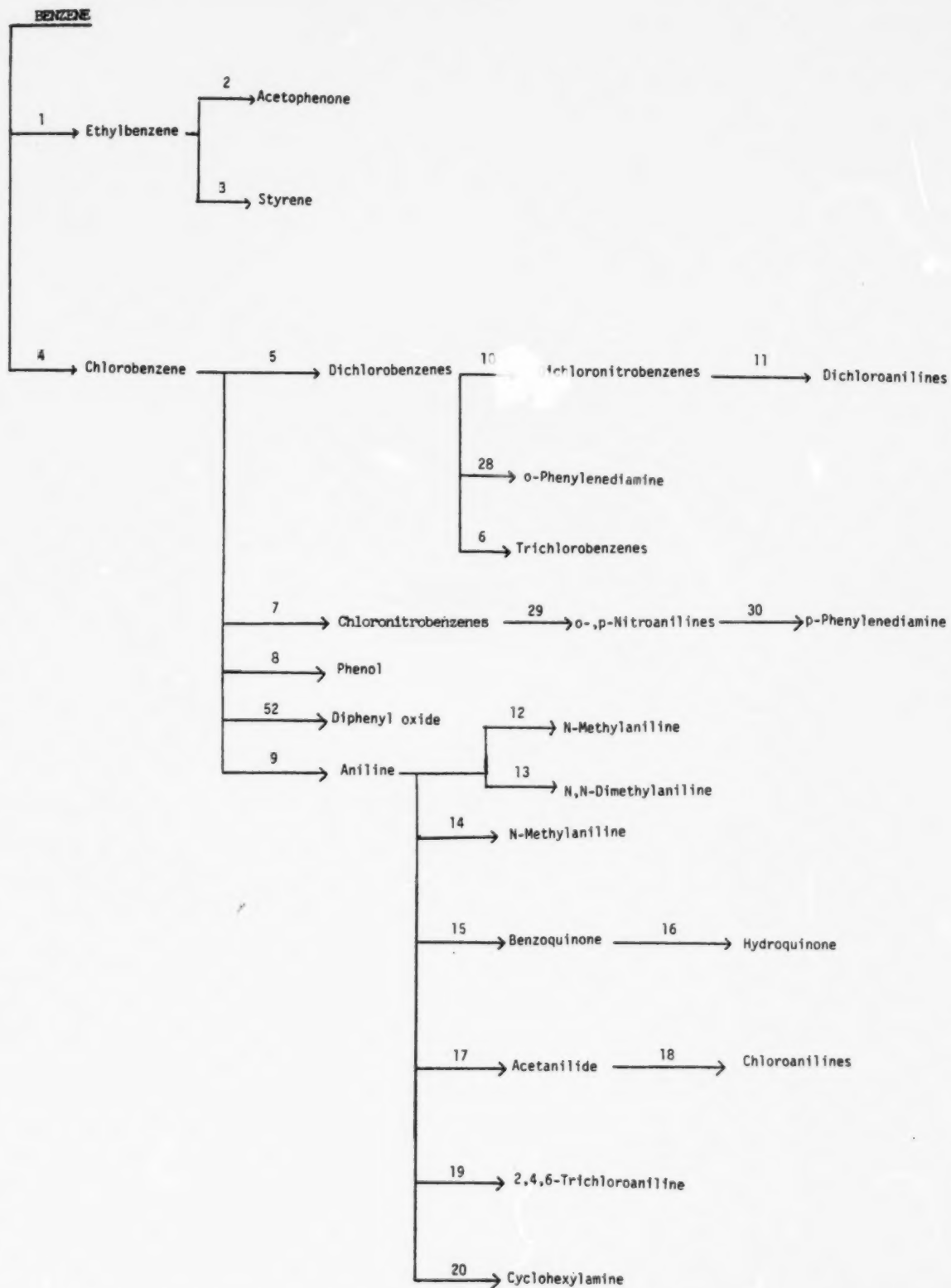


Figure 1. Benzene Section Chemical Tree  
6-36

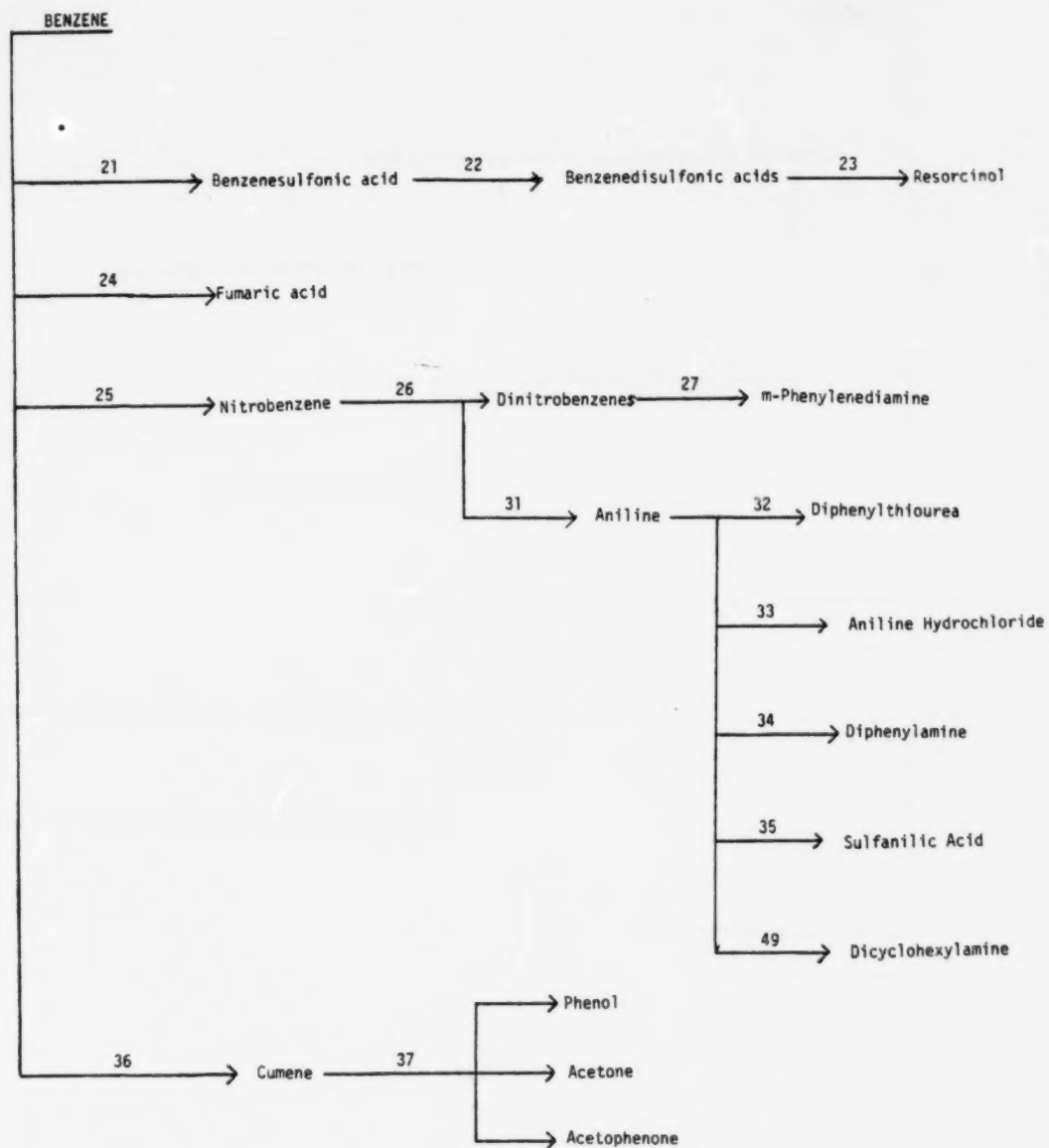


Figure 1. Benzene Section Chemical Tree (Cont.)

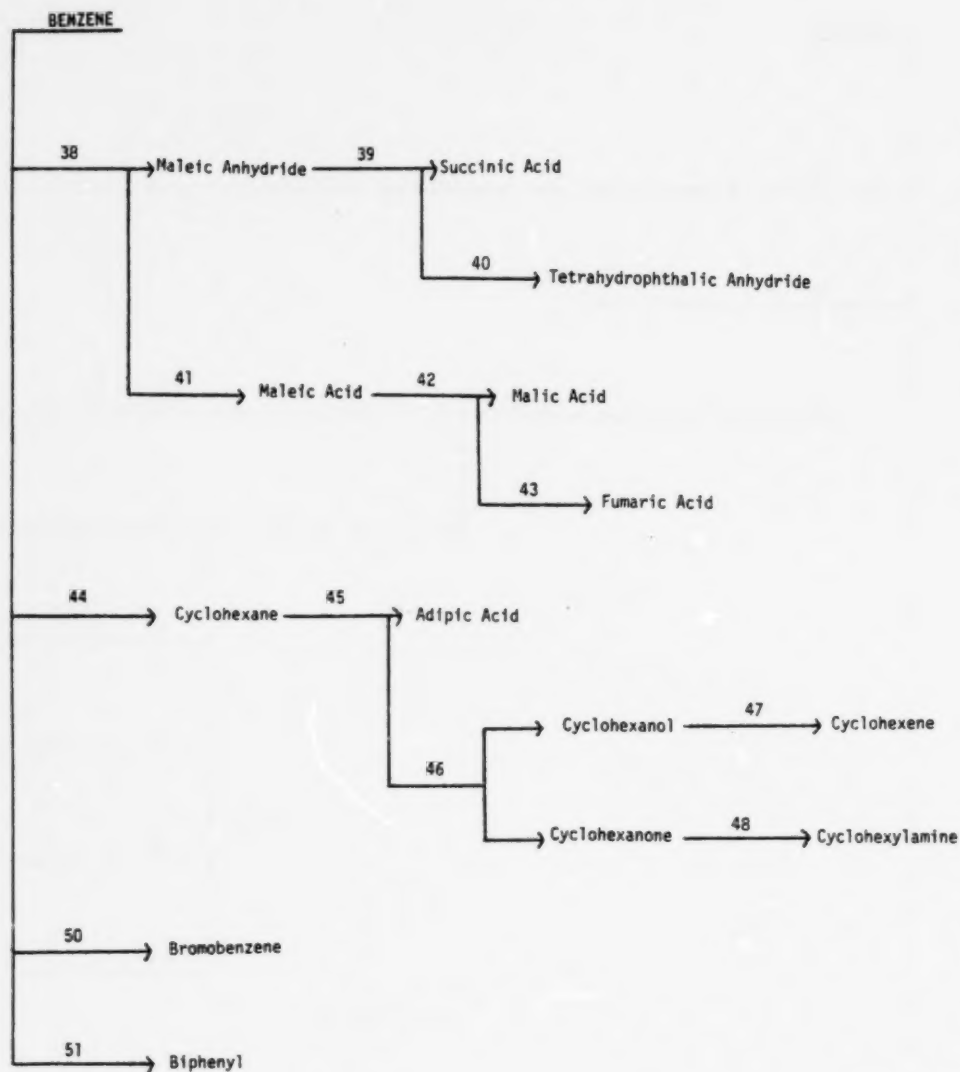


Figure 1. Benzene Section Chemical Tree (Cont.)

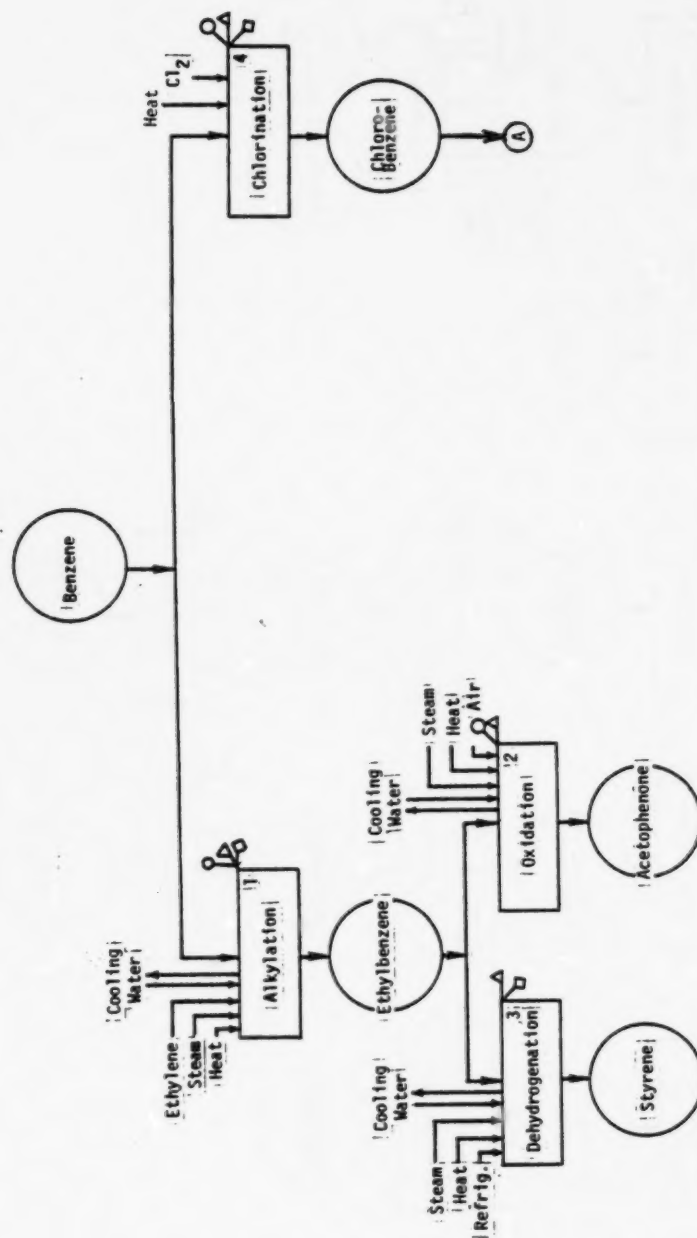


Figure 2. Benzene Section Process Flow Sheet



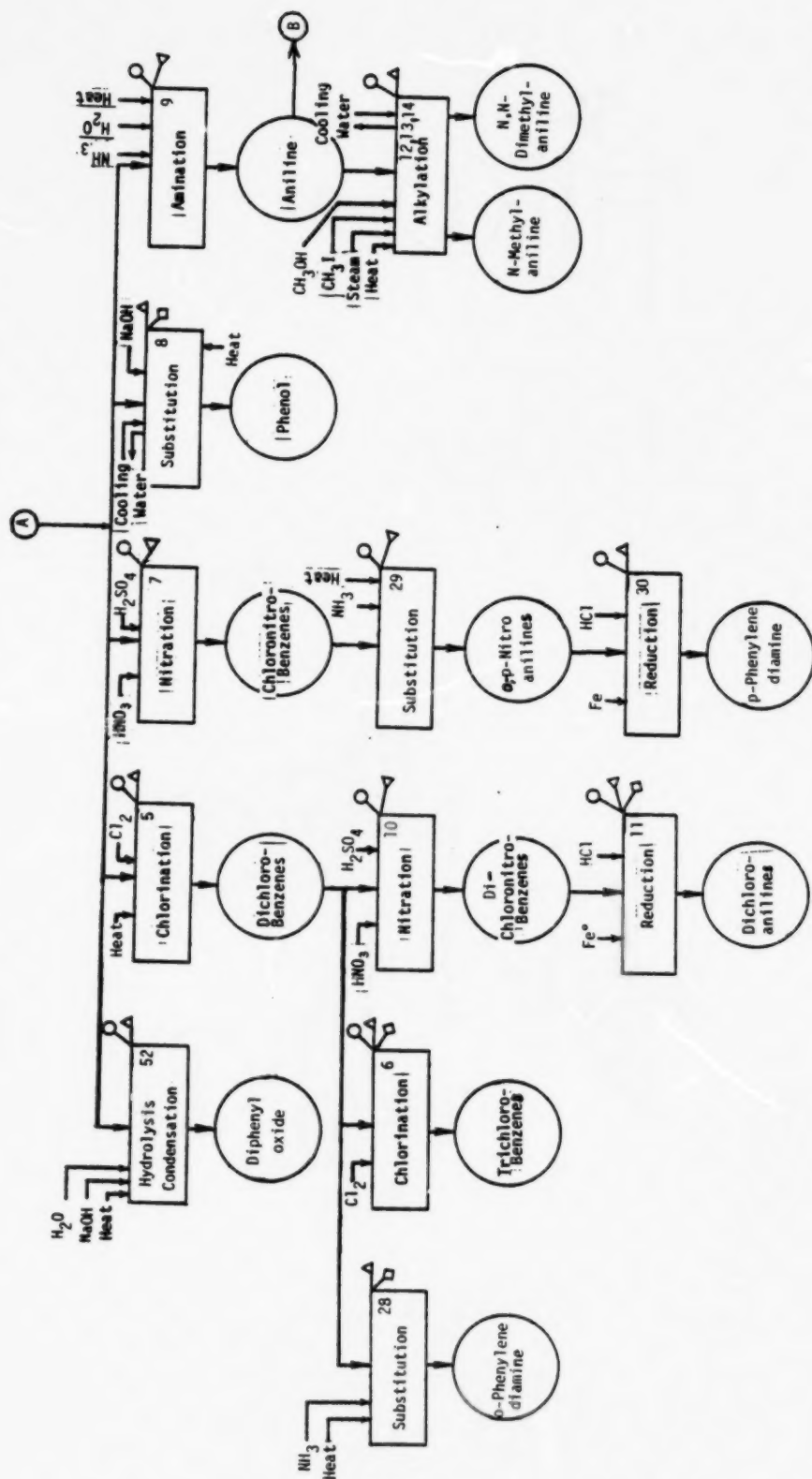


Figure 2. Benzene Section Process Flow Sheet (Cont.)

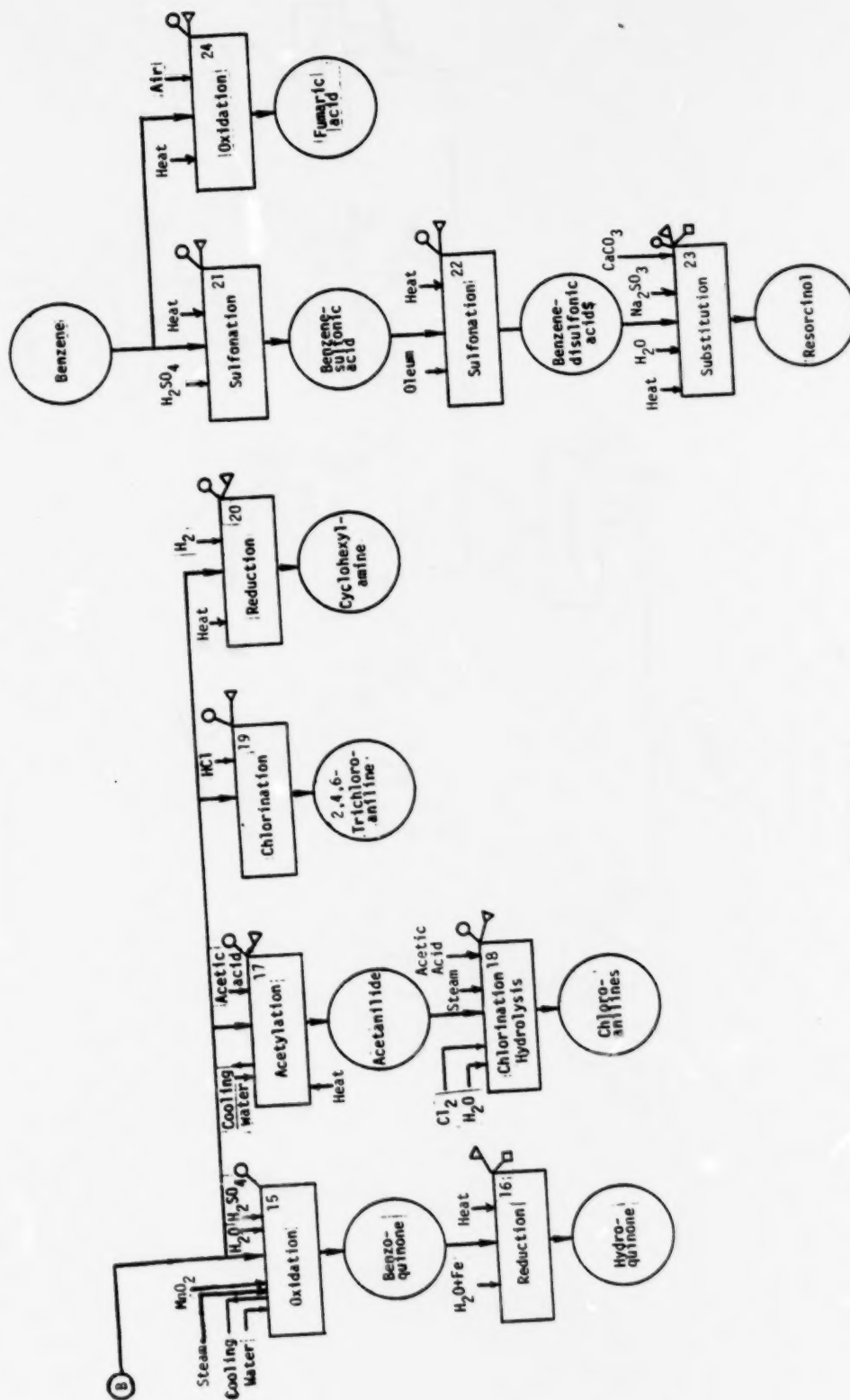


Figure 2. Benzene Section Process Flow Sheet (Cont.)

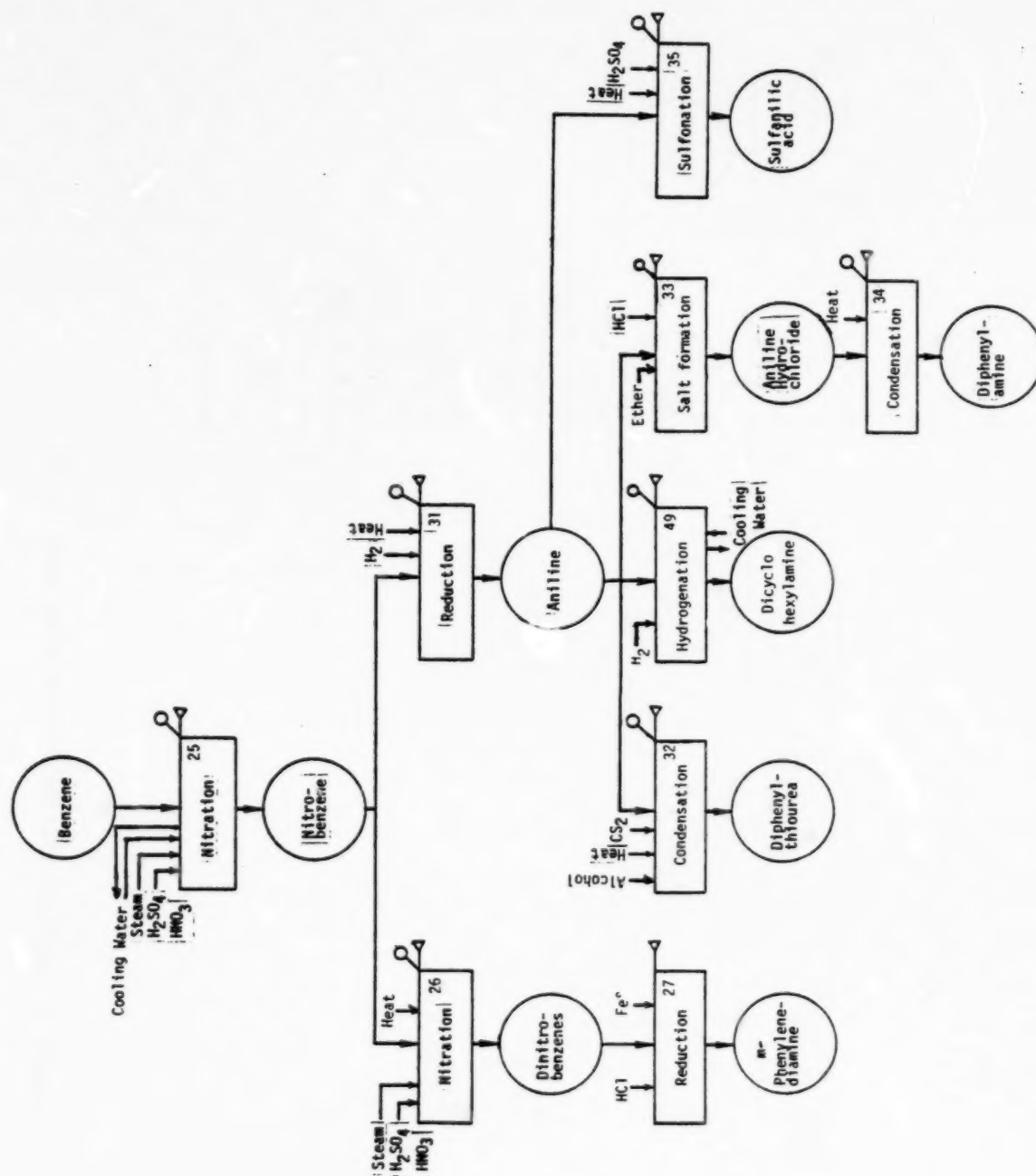


Figure 2. Benzene Section Process Flow Sheet (Cont.)

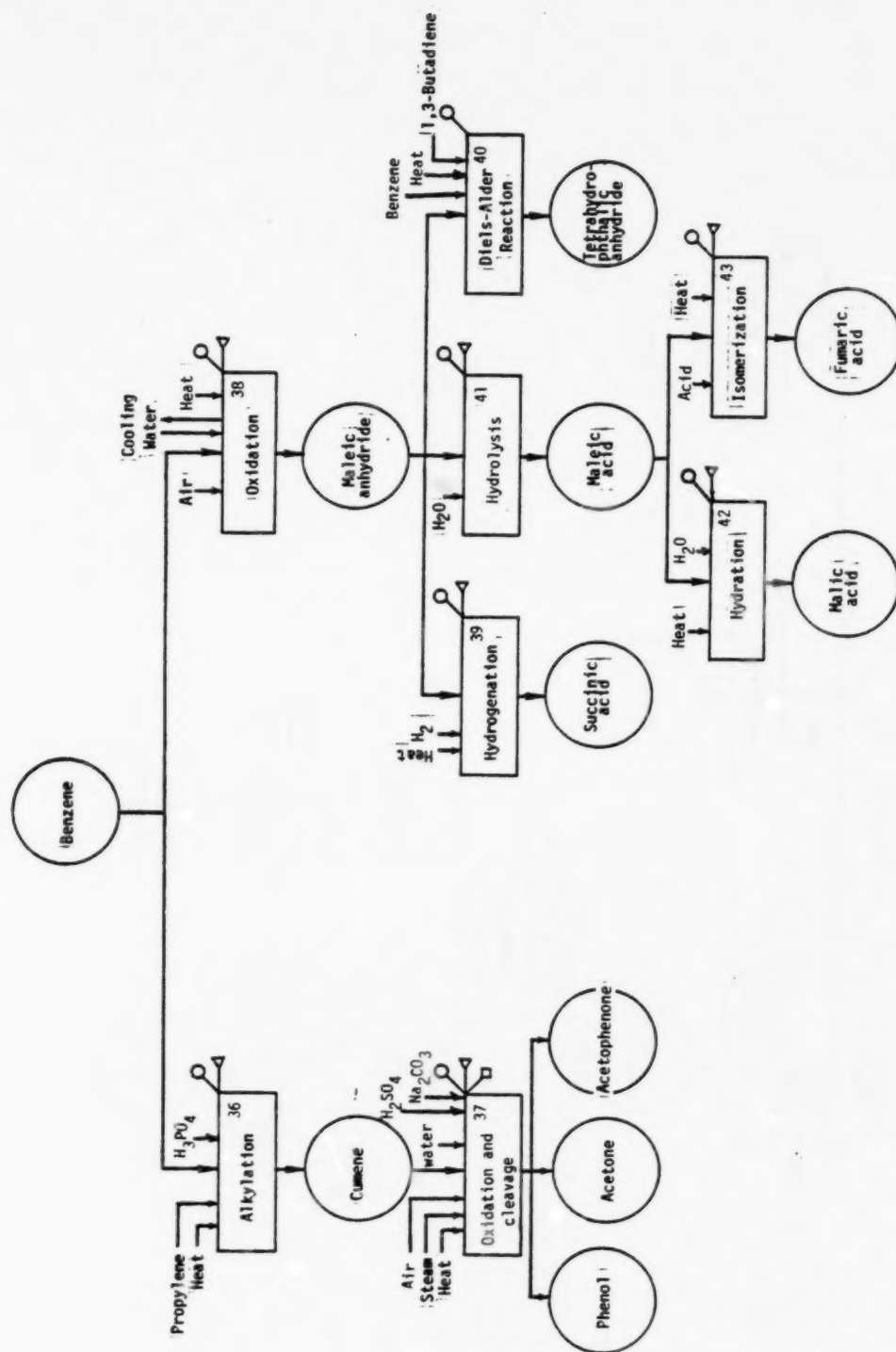


Figure 2. Benzene Section Process Flow Sheet (Cont.)

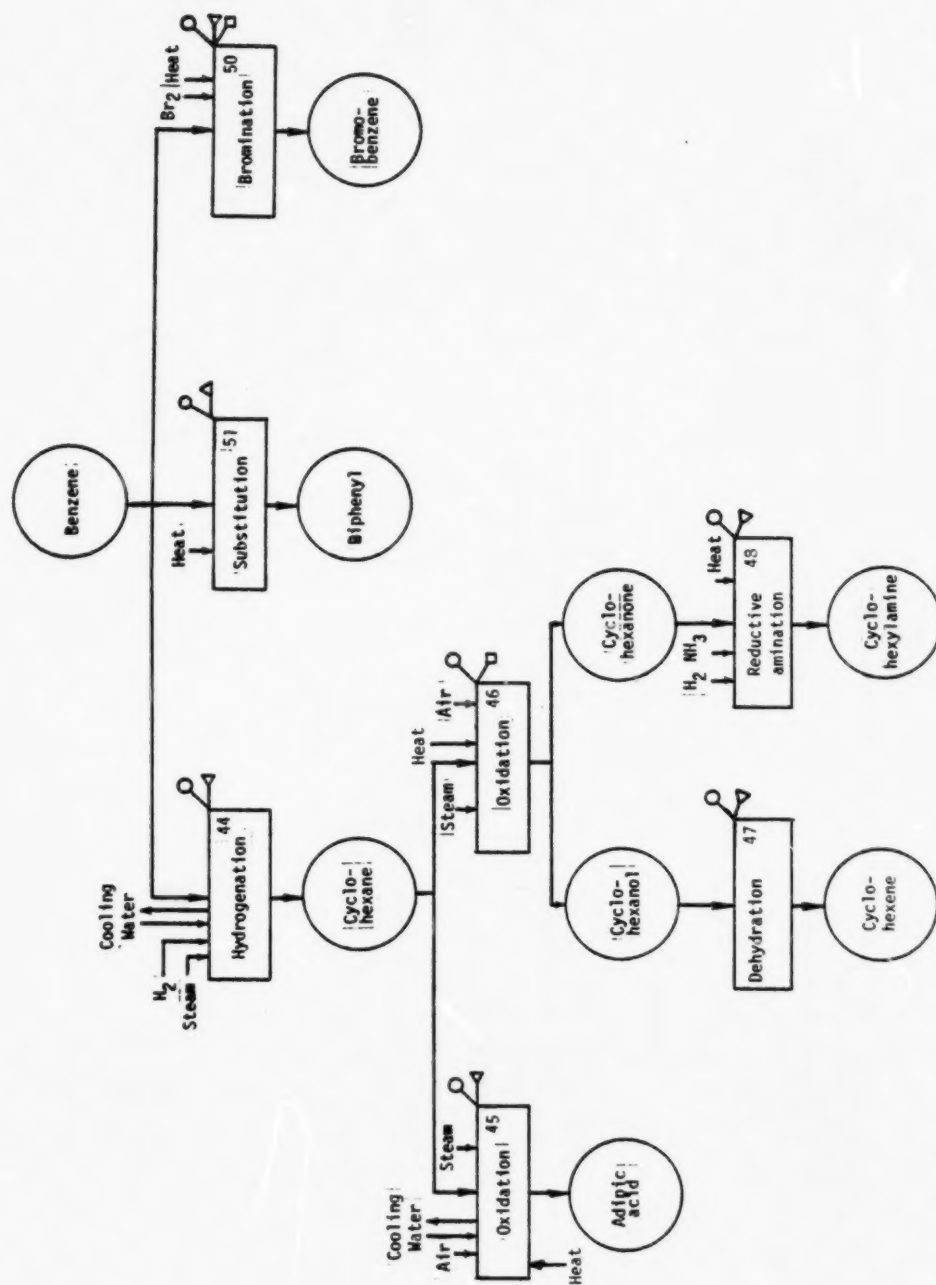
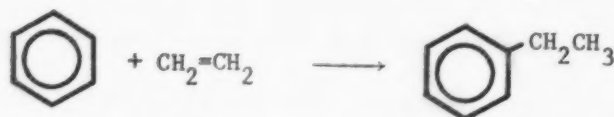


Figure 2. Benzene Section Process Flow Sheet (Cont.)

Ethylbenzene (from benzene and ethylene)

1. Function - Over 90% of ethylbenzene is produced synthetically and 10% is recovered by careful fractionation of selected gasoline fractions, or of the C<sub>8</sub> cut of aromatic naphtha.

Two synthetic processes are used, one of which involves a low-pressure liquid-phase reaction using aluminum chloride catalyst while the other operates in the vapor phase at high pressure with various solid catalysts.

The liquid-phase process is carried out in a brick-lined steel tower or a glass-lined reactor operating at the boiling point of the reaction mixture (80-100°C) at atmospheric pressure. The benzene used is known as "Styrene grade," which defines a benzene with a boiling range of 1°C and a minimum freezing point of 4.85°C (this ordinarily corresponds to a purity slightly above 99%). In general, ethylene at least 90% pure is used. Aluminum chloride is added to a reactor feed stream as a solid and forms the complex in the reactor. Benzene, both feed and recycle, enters the process through a benzene drying column. Hydrogen chloride in the form of HCl or ethyl chloride is also added to the reactor.

The liquid products from the alkylator are cooled and pass through a settler where the complex is removed and returned to the alkylator. The alkylate is then washed with water (which breaks any residual complex)



and scrubbed with 20% caustic soda for neutralization, after which it is separated into components in a series of distillation columns.

A prime example of a vapor-phase reaction is the Alkar process which offers the advantage of less corrosion than the aluminum chloride process and which can operate on refinery gas streams containing 8-10% ethylene. The temperature and pressure in this process are typically 290-310°C and 6.3 MPa, respectively. Fresh benzene is mixed with recycle benzene and ethylene and, after heating, is introduced into the fixed-bed alkylator. The high-pressure effluent is then flashed and fed into the benzene recycle column where the benzene is recovered as overhead product. The bottoms become the feed to the following column where the product ethylbenzene is separated from the (polyalkyl) benzenes. Most of the (polyalkyl) benzenes are recycled to a separate dealkylator along with the necessary benzene for conversion back to ethylbenzene. The dealkylator effluent is then combined with the alkylator effluent for flashing. The improved catalyst for the alkylation is apparently a boron trifluoride-modified anhydrous  $\gamma$ -alumina,  $\text{BF}_3$  being added also in the alkylator feed. The dealkylator presumably uses the identical catalyst and operates under less severe conditions (202°C and 3.45 MPa).

## 2. Input Materials

Benzene - 775 kg/Mg (1b/1000 lb) product

Ethylene - 270 kg/Mg (1b/1000 lb) product

### 3. Operating Parameters

Temperature: 80-100°C (176-212°F) (liquid phase)  
290-310°C (554-590°F) (vapor-phase alkylator)  
202°C (396°F) (vapor-phase dealkylator)

Pressure: atmospheric (liquid-phase)  
6.3 MPa (62.2 atm) (vapor-phase alkylator)  
3.55 MPa (35.0 atm) (vapor-phase dealkylator)

Catalysts: Aluminum chloride - HCl complex (liquid-phase)  
BF<sub>3</sub> on modified γ-alumina support (vapor-phase)

### 4. Utilities

Steam - 37.5 kg/Mg (1b/1000 lb) product

Cooling water - 300 kg/Mg (1b/1000 lb) product

Electricity - 76 MJ/Mg (9.6 kWh/1000 lb) product

Fuel - 5.0 GH/Mg (2.160 MM Btu/1000 lb) product

### 5. Waste Streams

Liquid-phase process:

Scrubber effluent (water) - benzene: 11 kg/Mg (1b/1000 lb)  
Hydrogen chloride: 3.9 kg/Mg (1b/1000 lb)

Separator effluent (water) - aluminum salts: trace  
tarry material: 26.6 kg/Mg (1b/1000 lb)

Vapor process: The major waste streams of this process are the spent caustic and washing streams from the crude alkylate washing step.

These streams will contain significant amounts of tars, benzene, ethylbenzene, and other polymers. The heavy aromatics fractions from the separation column are usually disposed of by incineration.

|                  |   |                                                                            |
|------------------|---|----------------------------------------------------------------------------|
| Flow             | - | $3.15 \times 10^{-4} \text{ m}^3/\text{kg}$ (37.7 gal/10 <sup>3</sup> lbs) |
| COD              | - | 5,980 mg/l<br>1.88 g/kg                                                    |
| BOD <sub>5</sub> | - | 433 mg/l<br>0.136 g/kg                                                     |
| TOC              | - | 2,091 mg/l<br>0.66 g/kg                                                    |

6. EPA Source Classification Code - None

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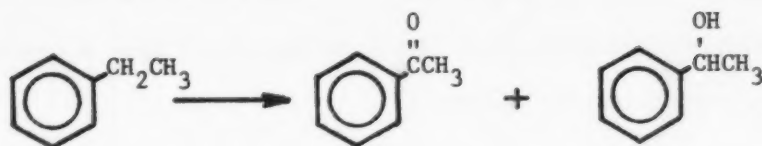
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Acetophenone (from ethylbenzene)

1. Function - Acetophenone is produced by the oxidation of ethylbenzene. The reaction is carried out in two acid proof, brick-lined reactors in series. Ethylbenzene and manganese acetate catalyst (15% aqueous solution) are fed into the top of the first reactor and air is dispersed into the liquid at the bottom. Liquid from the bottom of the first reactor is pumped to the top of the second reactor and more air is added at the bottom. The temperature is maintained at 126°C and the pressure at 308 kPa in both reactors. Total contact time between the air and ethylbenzene is 1.5 hours.

About 16% of the ethylbenzene is oxidized in the first reactor and an additional 10% in the second. Eighty-eight percent of the ethylbenzene that reacts forms acetophenone (2 parts) and  $\alpha$ -phenylethyl alcohol (1 part).

The remainder is oxidized to acids (including benzoic acid) and residue. The product is treated with 10% aqueous sodium hydroxide to extract acids and precipitate the manganese catalyst. Distillation of the organic layer yields ethylbenzene, which is recycled, and a mixture of acetophenone (68%) and  $\alpha$ -phenylethyl alcohol (32%).  $\alpha$ -Phenylethyl alcohol is dehydrogenated at 200°C in the presence of a catalyst with a stream of nitrogen flowing through the reactor to remove hydrogen. A mixture containing 80% acetophenone, 6%  $\alpha$ -phenylethyl alcohol, and

14% ethylbenzene is produced. Purified acetophenone is obtained by distillation. Purity control is achieved by controlling the freezing point of the distillate which is bulked to give a product with a minimum freezing point of 18.3°C.

2. Input Materials

Ethylbenzene - 1.176 Mg/Mg (1,176.5 lb/1000 lb) product

Air - 455 kg/Mg (1b/1000 lb) product

Nitrogen - Not given

Sodium hydroxide - Not given

Manganese acetate catalyst (15% aqueous solution) - Not given

3. Operating Parameters

Oxidation temperature - 126°C (259°F)

Oxidation pressure - 308 kPa (3.04 atm)

Dehydrogenation temperature - 200°C (392°F)

Product freezing point - 18.3°C (64.9°F) (minimum)

Catalyst - Manganese acetate (15% aqueous solution)

Contact time - 1.5 hrs.

4. Utilities - Basis - 0.454 kg (1 lb) of product

Electricity - 144 kJ (0.04 kWh)

Fuel gas - 9.06 dm<sup>3</sup> (0.32 cubic feet)

Cooling water - 102 dm<sup>3</sup> (27 gallons)

Steam - 3.2 kg (7.0 lb)

Compressed air - 404 dm<sup>3</sup> (14.3 cubic feet )

5. Waste Streams

Air: Excess air from the oxidation reactors and nitrogen from the dehydrogenator may be vented to the atmosphere and would contain ethylbenzene, acetophenone, and  $\alpha$ -phenylethyl alcohol in unknown quantities. Emission from distillation should be minimal.

Water: Still bottom residues, excess and sodium salts of by-product acids would be the major wastewater pollutants with possibly small quantities of ethylbenzene, acetophenone and  $\alpha$ -phenylethyl alcohol included.

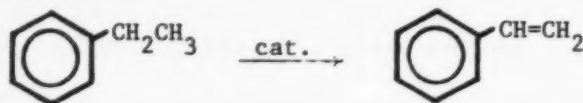
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Styrene (dehydrogenation of ethylbenzene)

1. Function - The present commercial process for styrene production involves the catalytic dehydrogenation of ethylbenzene. Dehydrogenation of ethylbenzene is effected at 600-700°C and atmospheric pressure in the presence of catalysts, e.g.,  $\text{SiO}_2\text{-Al}_2\text{O}_3$ , solid phosphoric acid, zinc oxide promoted with alumina and chromates, and cobalt oxides. Yields of 90% are commonly attained, with conversions of 30-40% per pass.

The styrene recovery section consists of three columns. The small amount of benzene and toluene produced by cracking is removed in the first column and returned to the ethylbenzene system. Ethylbenzene for recycle is separated from styrene in the second column, and polymerization inhibitors such as sulfur, para-tertiary butylcatechol or 2-nitro-4,6-dichlorophenol are added. In the third column, styrene monomer is separated from small amounts of tar and polymer formed during the operation.

2. Input Materials - Ethylbenzene - 1.12 kg/kg styrene
3. Operating Parameters

Temperature - 600-700°C (1112-1292°F)

Pressure - 101 kPa (1 atm)

Catalyst -  $\text{SiO}_2\text{-Al}_2\text{O}_3$ , solid phosphoric acid, ZnO promoted with alumina and chromates, cobalt oxides.

4. Utilities - Basis: 2.87 kg/sec (6.3 lb/sec) capacity

|                       | <u>Dehydro-<br/>genation</u> | <u>Separ-<br/>ation</u> | <u>Total</u> |
|-----------------------|------------------------------|-------------------------|--------------|
| <u>Steam</u>          |                              |                         |              |
| kg/sec                | 27.2                         | 13.1                    | 40.3         |
| (lb/sec)              | (60)                         | (28.9)                  | (88.9)       |
| <u>Cooling</u>        |                              |                         |              |
| <u>Water</u>          |                              |                         |              |
| m <sup>3</sup> /sec   | 0.94                         | 0.64                    | 1.58         |
| (gals/sec)            | (248)                        | (169)                   | (417)        |
| <u>Refrigeration</u>  |                              |                         |              |
| Mg                    | 27.2                         | 90.7                    | 117.9        |
| (tons)                | (30)                         | (100)                   | (130)        |
| <u>Natural Gas</u>    |                              |                         |              |
| sm <sup>3</sup> /sec  | 0.17                         |                         | 0.17         |
| (scf/sec)             | (6)                          |                         | (6)          |
| <u>Electric Power</u> |                              |                         |              |
| (kW capacity)         |                              |                         |              |
| Process               | 108                          | 160                     | 268          |
| Utilities             | 466                          | 270                     | 736          |

5. Waste Streams - Separator (water)

Heavy ends and tarry matter\* - 0.393 kg/Mg (1b/1000 lb) styrene

Super heater (water) tarry matter\* and heavy ends - 5.9 kg/Mg (1b/1000 lb) styrene

Still bottom (solids) tarry matter\* and heavy ends - 7.05 kg/Mg (1b/1000 lb) styrene

|                  | <u>Plant 1</u>                                                | <u>Plant 2</u>                                               |
|------------------|---------------------------------------------------------------|--------------------------------------------------------------|
| Flow             | 0.0235 m <sup>3</sup> /kg (2,810 gal/<br>10 <sup>3</sup> lbs) | 0.00548 m <sup>3</sup> /kg (657 gal/<br>10 <sup>3</sup> lbs) |
| COD              | 219 mg/l<br>5.13 g/kg                                         | 426 mg/l<br>2.34 g/kg                                        |
| BOD <sub>5</sub> | 69 mg/l<br>1.62 g/kg                                          | 70 mg/l<br>0.381 g/kg                                        |
| TOC              | 22 mg/l<br>0.53 g/kg                                          | 22 mg/l<br>0.12 g/kg                                         |

\* Contains styrene trimer, stilbene, biphenylnaphthalene, phenanthrene, ethylphenanthrene, and other unidentifiable products.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 113,114.

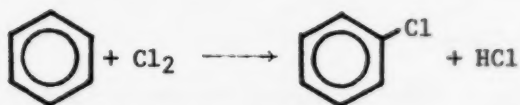
"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973, p. 179,180.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 63-67.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 191-195.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 779-782.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November, 1975, p. 204,205.

Chlorobenzene

1. Function - Chlorobenzene is manufactured by passing dry chlorine into benzene in the presence of a catalyst. The catalysts which may be used are molybdenum chloride,  $\text{FeCl}_3$ ,  $\text{AlCl}_3$ , Fuller's earth, or simply iron turnings. The reaction takes place in a boiling mixture of chlorobenzene and benzene at 101 kilopascals (1 atmosphere) pressure and 80-100°C (175-212°F). HCl released by the reaction is scrubbed with recycled benzene to remove hydrocarbons and then absorbed with water to form 20°Be hydrochloric acid. The bottoms are washed with sodium hydroxide to remove remaining HCl and dichlorobenzenes. The sodium hydroxide solution is decanted and the product fed to a stripping column where benzene is stripped off overhead and recycled to the HCl scrubber. The bottoms are fed to a fractionating column where the pure monochlorobenzene is taken off overhead.
2. Input Materials - Basis - 1 metric ton chlorobenzene  
Chlorine - 875 kg (1929 lbs)  
Benzene - 950 kg (2094 lbs)  
Sodium hydroxide  
Catalyst (Fe turnings) - small
3. Operating Parameters  
Temperature - 80-100°C (175-212°F)  
Pressure - 101 kPa (1 atm)  
Catalyst - molybdenum chloride  $\text{FeCl}_3$ ,  $\text{AlCl}_3$ , fuller's earth, iron turnings

4. Utilities

Electric power - Not given

Water - Not given

5. Waste Streams - Main pollutant by-products are: HCl, dichlorobenzene, heavies and spent caustic sludge. The HCl and dichlorobenzenes are absorbed. Benzene is also a major air pollutant. Two sources are the vent on the HCl absorber and on the stripper.

6. EPA Source Classification Code - None

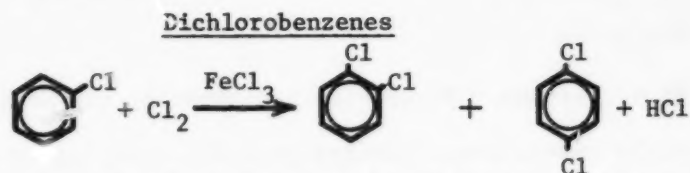
7. References

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 103-104.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 128.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 373.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 258-260.



1. Function - Dichlorobenzenes can be produced by chlorinating chlorobenzene in the presence of ferric chloride at 150-190°C. This reaction produces basically a mixture of o- and p-dichlorobenzenes with the latter predominating. The ortho isomer can be removed from the crystalline para isomer by washing the crystals of the para isomer with methanol. The p-dichlorobenzene is finally freed from alcohol by heating at 100°C under vacuum. The meta isomer of dichlorobenzene does not occur in high enough quantities in the above reaction process to make it a practicable source of that isomer. Usually, m-dichlorobenzene is obtained from the ortho and para isomer by subjecting these to an isomerizing process. This isomerizing process is to heat the mixture to 120°C under approximately  $4.5 \times 10^3$  kilopascals in the presence of aluminum chloride and hydrogen chloride; aluminum chloride in a small amount of water; or aluminum chloride alone at higher temperature.

2. Input Materials

Chlorobenzene

Ferric chloride

Chlorine

3. Operating Parameters

Temperature: 150-190°C (302-374°F)

Pressure: not given



4. Utilities

Not given

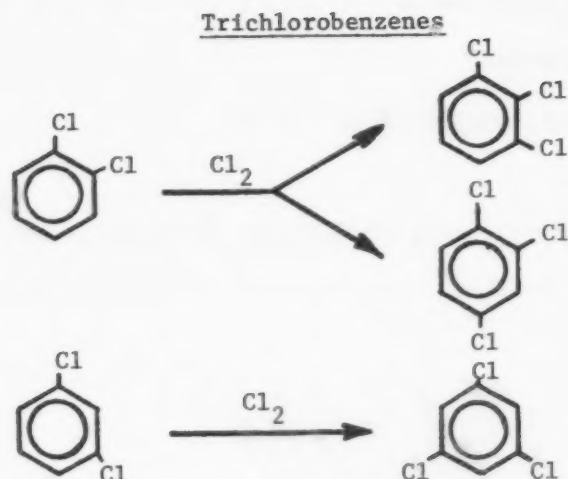
5. Waste Streams - No specific information was available, but one would expect some hydrogen chloride to be given off and possibly some benzene, trichlorobenzene, and ionic salts.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 259-260.

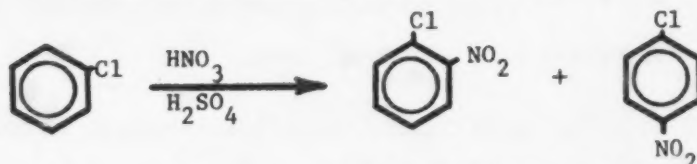
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 213.



1. Function - The 1,2,3- and 1,2,4-isomers of trichlorobenzene can be obtained by chlorinating o-dichlorobenzene at 25-30°C, in the presence of ferric chloride, to a density of 1.4 (at 15°C), neutralizing the acid present, and fractionally distilling. Similarly, by chlorinating m-dichlorobenzene, 1,3,5 trichlorobenzene can be obtained.
2. Input Materials
  - Dichlorobenzenes
  - Ferric chloride
  - Chlorine gas
3. Operating Parameters
  - Temperature - 25-30°C (77-86°F)
  - Pressure - not given
  - Catalyst - ferric chloride
4. Utilities - Not given

5. Waste Streams - Waste water from distillation bottoms may contain traces of dichlorobenzenes and trichlorobenzenes, as well as polychlorinated benzenes.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1964) p. 260-262.

Chloronitrobenzenes (from chlorobenzene)

1. Function- Chloronitrobenzenes can be manufactured by the nitration of chlorobenzene using a mixed acid of nitric acid and sulfuric acid. Since the chlorine is ortho-para directing the substitution into the ring with the nitric group is on the ortho (34%) and para (65%) positions. Thus the product from this reaction is a mixture of ortho and para chloronitrobenzenes. The para isomer is separated by recrystallization. The o-chloronitrobenzene is purified by rectification.
2. Input Materials  
Chlorobenzene - 4536 kg (10,000 lbs)  
Nitric acid (30-35%)  
Sulfuric acid (52-55%) } 9,570 kg (21,100 lbs)
3. Operating Parameters  
Temperature - 40-70°C (104-158°F)  
Pressure - not given  
Reaction time - 12 hrs.
4. Utilities - Not given
5. Waste Streams - Possible aromatic emissions from the distillation process; possible  $\text{NO}_x$  emissions during nitration process and acid wastes.
6. EPA Source Classification Code - None

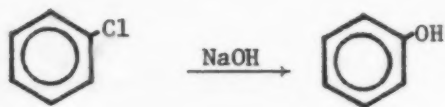
7. References

Hedley, W. H., et al., Potential Pollutants From Petrochemical Processes, Technomic Publishing Co., Westport, Conn., 1975.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3," "Chemical Engineering," March 18, 1974, p. 90.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 552.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 172,173.

Phenol (from chlorobenzene)

1. Function - Phenol is formed from chlorobenzene by reacting the chlorobenzene with sodium hydroxide at elevated temperature and pressure. In this process, chlorobenzene and a 10 - 15% aqueous sodium hydroxide solution are introduced into a high pressure pump with approximately 10% by weight of diphenyl oxide. Small quantities of anti-corrosion agents, emulsifiers, and a catalyst may also be added to the reactants. This process stream is fed to a continuous-flow tubular reactor system in which the stream temperature is raised to 400°C (752°F) approximately  $27.6 \times 10^3$  -  $34.5 \times 10^3$  kilopascals (4000 - 5000 psi) and maintained at this temperature and pressure for 10 - 30 minutes. The heat exchanger in which this reaction is carried out is a steel pipe, nickel-lined exchanger using flue gas, and organic heat transfer agent, direct flame, or electrical heating coils as a heat transfer medium. After leaving the exchanger the product stream is cooled. The reaction products, consisting of sodium phenate, sodium chloride, water, and unchanged reactants, produce a two phase system. The first phase is an aqueous phase containing sodium phenate, and the second phase is an oil phase consisting principally of diphenyl oxidate and unreacted monochlorobenzene. The oil phase is distilled to produce diphenyl oxide or is recycled to the reactor. The aqueous phase is treated with hydrochloric acid to convert sodium phenate to phenol which is decanted and distilled under vacuum. The sodium



chloride that is formed is electrolyzed to form sodium hydroxide and chlorine which is recycled.

2. Input Materials

Chlorobenzene - 1.27 kg (lb)/kg (lb) phenol produced

Aqueous sodium hydroxide - 0.12 kg/Mg (0.24 lb/ton) phenol produced

Diphenoloxide - 0.13 kg (lb)/kg (lb) phenol produced

3. Operating Parameters

Temperature: 400°C (752°F)

Pressure:  $27.6 \times 10^3$  -  $34.5 \times 10^3$  kilopascals (4000 - 5000 psi)

Catalyst: not given

4. Utilities

Electric power - not given

Cooling water - 3.85 kg (lb)/kg (lb) phenol produced

5. Waste Streams

Acid stream dichlorobenzene column (water):

Chlorobenzene

Dichlorobenzene

Other chlorinated compounds (assumed to be mainly chlorotoluene) -  
4.0 kg/Mg (7.9 lb/ton) phenol

Ortho-dichlorobenzene column waste (solid):

Ortho-dichlorobenzene - 0.6 kg/Mg (1.2 lb/ton) phenol

Other chlorinated compounds (chlorotoluene) - 1.2 kg/Mg (2.4 lb/ton)  
phenol

Extractor brine (water):

Phenol - 0.75 kg/Mg (1.5 lb/ton) phenol

Sodium chloride - 1.559 kg/Mg (3,118 lb/ton) phenol

Benzene - 12.2 kg/Mg (24.4 lb/ton) phenol

Diphenyl ether column wastes (solid):

Diphenyl ether - 0.665 kg/Mg (1.33 lb/ton) phenol

Phenyl diphenyl ether - 19.4 kg/Mg (38.7 lb/ton) phenol

6. EPA Source Classification Code - None

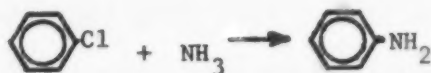
7. References

Yen, Y. C., "Phenol," Report No. 22, Stanford Research Institute,  
Menlo Park, California, 1967.

Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corporation, Park Ridge, N.J., 1974, p. 181.

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 8," "Chemical Engineering," July 22, 1974, p. 107, 108.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 153-155.

Aniline

1. Function - Aniline is produced by combining chlorobenzene, and liquid ammonia at high temperatures and high pressures in the presence of a catalyst. The catalyst used is the cuprous chloride made from the reaction of the cuprous oxide and ammonium chloride. The reaction takes place at 200°C and 6.2 megapascals (900 psi).
2. Input Materials - Basis - 1 metric ton aniline  
Chlorobenzene - 1250 kg (2,756 lbs)  
Cuprous oxide - 175 kg (386 lbs)  
Liquid ammonia - (28% solution) 3725 kg (8,212 lbs)  
NH<sub>3</sub>: C<sub>6</sub>H<sub>5</sub>Cl ratio should be at least 5:1
3. Operating Parameters  
Temperature: 180-220°C (356-428°F)  
Pressure - 6.2 MPa (61.2 atm)
4. Utilities  
Electric power - not given  
Water - not given
5. Waste Streams  
Ammonia  
Benzene  
Phenol

6. EPA Source Classification Code - None

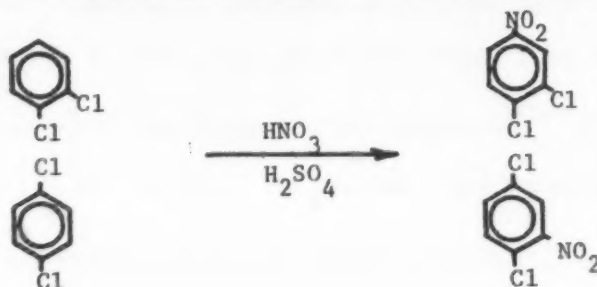
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 419.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1",  
"Chemical Engineering," January 21, 1974, p. 132.

Astle, M. J., Industrial Organic Nitrogen Compounds, Reinhold Publishing  
Corp., New York, N.Y., 1961, p. 87.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition  
John Wiley and Sons, New York, N.Y., 1975, p. 111,112.

Dichloronitrobenzenes (from dichlorobenzenes)

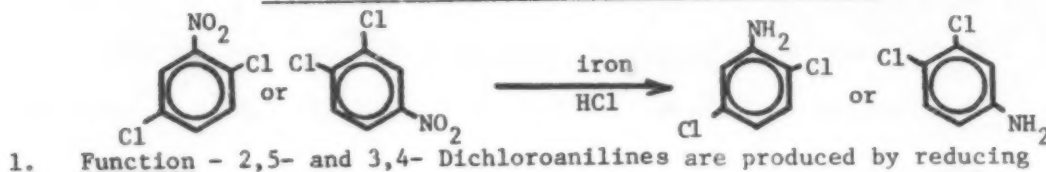
1. Function - The dichloronitrobenzenes (3,4-dichloro- and 2,5-dichloro-1-nitrobenzenes) are prepared commercially by nitrating their corresponding dichlorobenzenes. In many cases two immiscible layers are present in the nitrator. For safety reasons and ease of operation, atmospheric pressures and temperatures from 0-120°C are used. At the higher temperatures, competing oxidation reactions becomes important.
2. Input Materials  
Dichlorobenzenes  
Nitric acid  
Sulfuric acid
3. Operating Parameters  
Temperature - 0-120°C (32-248°F)  
Pressure - 101 kPa (1 atm)  
Residence Time - 1-60 minutes
4. Utilities - Not given
5. Waste Streams - Some chlorinated benzenes, chloronitro-phenols, nitric, and sulfuric acid may be present in the waste streams.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 785-790,  
244.



Dichloroanilines (from dichloronitrobenzene)2. Input Materials

Dichloronitrobenzene

Iron

HCl

Hydrogen

Catalyst

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst: not given

4. Utilities - not given5. Waste Streams - Waste acid and some iron sludge should be present in the aqueous waste streams.6. EPA Source Classification Code - None7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2(1963) p. 424.

N-Methyl Aniline (from aniline and methanol)

1. Function - N-Methyl aniline is most economically produced by the vapor - phase reaction of aniline and methanol at 285-325°C over a catalyst containing 86% alumina, 9% calcium oxide (or  $\text{ZnO}$ ,  $\text{CrO}$ ,  $\text{MgO}$ ,  $\text{FeO}$ ,  $\text{MnO}$ ), and 5% (2-20%) copper.

Tertiary amine formation is suppressed by the use of hydrogen at 207 - 414 kPa (2.04 - 4.09 atm). Yields of 96-98% are obtained.

2. Input Materials - Basis: 1 kg N-Methyl aniline

|          |         |
|----------|---------|
| Aniline  | 0.90 kg |
| Methanol | 0.46 kg |
| Hydrogen | 4.8 g   |

3. Operating Parameters

Temperature: 285-325°C (545-617°F)

Pressure: 101 kPa (1 atm)

Catalyst: 86% alumina, 9%  $\text{CaO}$ , 5% copper

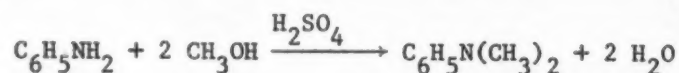
4. Utilities - not given
5. Waste Streams - Off-gases from the separator may contain methanol, aniline, methyl aniline and by-products such as N,N-dimethyl aniline.

6. EPA Source Classification Code - 3-01-034-01

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963) p. 368,420.

U.S. Patent No. 2,580,284 (Dec. 25, 1951)

N,N-Dimethylaniline (from aniline and methanol)

1. Function - Dimethylaniline is produced by heating aniline and methanol under pressure in an autoclave with an acid catalyst, commonly hydrochloric or sulfuric acid. Sulfuric acid is used commercially since it is less corrosive than hydrochloric acid. The aniline, methanol, and sulfuric acid are mixed together, stirred (to suspend the aniline sulfate which precipitates out), and pumped into an unlined steel autoclave. The autoclave is heated (93.3-121.1°C superheat given to steam at 689.5 kPa) during the course of two hours to around 200°C and kept there for five or six hours, during which time the internal pressure may rise to 3,620-3,792 kPa. The autoclave may be allowed to cool or the hot mixture may be discharged through a cooling condenser into a vessel where the acid is neutralized with caustic soda. Vacuum distillation allows the recovery of excess methanol and purification of the dimethylaniline produced.

2. Input Materials - Basis - 1 metric ton product

|                           |        |
|---------------------------|--------|
| Aniline, kg               | 1052.6 |
| Methanol, kg              | 1158.1 |
| Sulfuric acid (66° Be) kg | 105.5  |

3. Operating Parameters

|                    |                         |                 |
|--------------------|-------------------------|-----------------|
| Temperature, °C    | 200                     | (392°F)         |
| Pressure, kPa      | 3,620-3,792             | (35.7-37.4 atm) |
| Reaction time, hrs | 5-6                     |                 |
| Reaction Vessel:   | unlined steel autoclave |                 |

4. Utilities

Not given

5. Waste Streams - Specific information was not available, but some aniline, monomethylaniline, and sulfate salts may be in the waste water.

6. EPA Source Classification Code - None

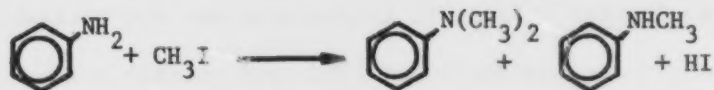
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 420.

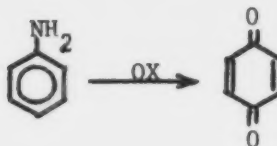
Groggins, P. H., Unit Processes in Organic Synthesis, 5th Ed., McGraw-Hill Book Co., New York, N.Y., 1958 , p. 850, 851.

Shreve, R.N., Chemical Process Industries, 3rd Ed., McGraw-Hill Book Co., New York, N.Y., 1967 , p. 821, 822.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 275.

N-Methyl Aniline (from aniline and methyl iodide)

1. Function - An alternate route to N-methyl aniline involves the reaction of aniline and methyl iodide at elevated temperatures. This results in a mixture of N-methyl aniline and N,N-dimethyl aniline, which may be separated by a series of distillations.
2. Input Materials  
Aniline  
Methyl iodide
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - The water effluent from the acid scrubber probably contains sodium iodide, caustic, methyl iodide, aniline, and traces of the secondary and tertiary amines. Methyl iodide and hydrogen iodide may be present in the gas effluent.
6. EPA Source Classification Code - 3-01-034-01
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963) p. 420.

p-Benzoquinone

1. Function - p-Benzoquinone is manufactured by the oxidation of aniline as the sulfate salt with sodium dichromate or manganese dioxide mixed with sulfuric acid. Dilute sulfuric acid and approximately 25% of the total  $\text{MnO}_2$  is charged to the oxidizing tank. This mix is cooled to 5-12°C, then a solution of the aniline and sulfuric acid is added to the tank. The remainder of the  $\text{MnO}_2$  is added so that there is always an excess of  $\text{MnO}_2$  in the tank. Cooling is a critical factor since this reaction is very exothermic. A variation of this process operates at 20-70°C and continuously at reduced pressure. After completion of the reaction the acidity is reduced by addition of a hydrated lime slurry and the p-benzoquinone is distilled with steam. The distillate is then chilled to form golden-yellow needles of a 99-100% purity product.

The non-volatile mineral salts are used as a source of manganese in fertilizer and animal feed supplements.

Often a marked increase in yield results if the substance contains an additional hydroxyl or amino group in the para position.

2. Input Materials - Basis: 1 kg p-Benzoquinone produced

Aniline - 0.85 kg

$\text{MnO}_2$  - 2.42 kg

$\text{H}_2\text{SO}_4$  - 4.19 kg

Water - 14.65 kg



3. Operating Parameters

Temperature: 5-12°C (41-54°F) initial or 20-70°F (68-158°F) in modified case

Pressure: not given

Catalyst: none

4. Utilities

Not given

5. Waste Streams - ammonia from distillation

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 415.

Ibid, Vol. 16 (1967), p. 907.

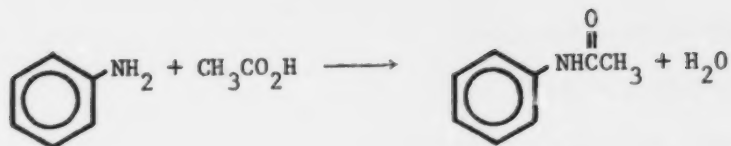
Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4 (1972), p. 402,405.

Carson, J., Organic Reactions, John Wiley & Sons, New York, N.Y., Vol. 4 (1949), p. 306

Hydroquinone

1. Function - Hydroquinone is manufactured by reducing p-benzoquinone. This is done with the quinone in solution with iron dust and water at 60 - 76°C (140 - 149°F) and a slightly reduced pressure. The reaction mixture is filtered to remove iron oxide, and excess iron and the filtrate passed to crystallizers. In some processes the pure-white technical product obtained is purified by vacuum distillation. The distilled product is then dissolved in dilute sulfuric acid bath with the use of carbon, sodium bisulfite, or zinc dust as decolorizing agents. The solution is then filtered and a small amount of sodium hydrosulfite is added to the filtrate from which the hydroquinone crystallizes.
2. Input Materials - per kg (lb) hydroquinone produced  
p-Benzoquinone - 1.25 kg (lb)  
Iron dust - 12.5 kg (lb)  
Water - 100 kg (lb)
3. Operating Parameters  
Temperature: 60 - 65°C (140 - 149°F)  
Pressure: slightly reduced  
Catalyst: none
4. Utilities  
Electric power - not given  
Water - not given

5. Waste Streams - possible sludge handling problems, starting material, and phenolic resins.
6. EPA Source Classification Code - Code
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 11 (1966), p. 485-487.

Acetanilide

1. Function - Acetanilide can be manufactured in two major ways. The first uses a benzene solution of aniline and acetic acid and acetyl chloride. This solution is refluxed in a jacketed, enameled still until no free aniline remains. The reaction mixture is filtered and the crystals separating on cooling are recrystallized from hot water.

The second process employs aniline and approximately 100% molar excess of acetic acid. This solution is refluxed for 6 to 14 hours in a suitable still. The product is dropped into hot water and allowed to crystallize. If the acid is dilute the reaction is carried out under pressure at 150-160°C (302-320°F).

2. Input Materials

Process one

Aniline - 0.69 kg (1b)/kg (1b) acetanilide

Acetic acid - 0.97 kg (1b)/kg (1b) acetanilide

Benzene - as needed

Process two

Aniline - 0.69 kg (1b)/kg (1b) acetanilide

Acetic acid - 0.76 kg (1b)/kg (1b) acetanilide

3. Operating Parameters

Temperature - 150-160°C (302-320°F)

Pressure - Not given

Catalyst - None

Reaction time - 6-14 hrs

4. Utilities

Electric power - Not given

Water - Not given

5. Waste Streams - Benzene from refluxing operations and some acetic acid.

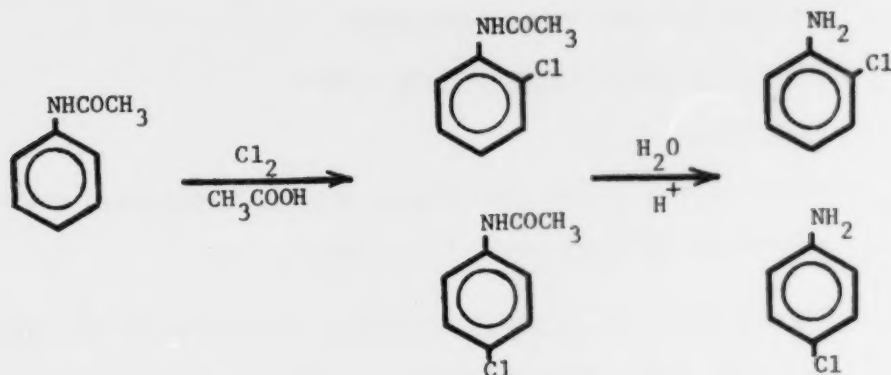
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 151.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 526.

Faith, W. L., et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N.Y., 1965, p. 9,10.

Chloroanilines (from acetanilide)

1. Function - Acetanilide is mixed with acetic acid and chlorine gas to produce a mixture of o- and p-chloroacetanilides. This mixture is then combined with water and acid to produce a mixture of o- and p-chloroanilines. The mixture can then be separated by steam distillation.

The production of m-chloroaniline is by the reduction of m-nitrochlorobenzene or by treating aniline in concentrated sulfuric acid with chlorine gas.

2. Input Materials

Acetanilide

Acetic acid

Chlorine

Water

3. Operating Parameters

Temperature - not given

Pressure - not given

Catalyst - none

4. Utilities - not given



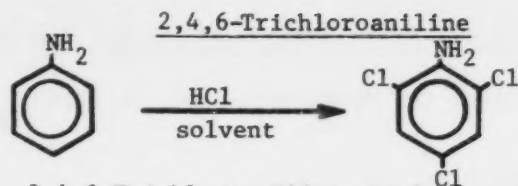
5. Waste Streams - Possible chlorine gas from incomplete reaction in initial step and some acetic acid.

6. EPA Source Classification Code - None

7. References

Astle, M. J., Industrial Organic Nitrogen Compounds, Rheinhold Publishing Co., New York, N.Y., 1961, p. 109.

Migradichian, V., Organic Synthesis, Rheinhold Publishing Co., New York, N.Y., Vol. 2 (1957), p. 1555.



1. Function - 2,4,6-Trichloroaniline can be manufactured by the direct chlorination of aniline according to the above reaction. In this reaction anhydrous hydrochloric acid in an anhydrous organic solvent is mixed with aniline to produce the 2,4,6-trichloroaniline, which is diluted with water, separated, and dried at 60°C/2.66 kPa.
2. Input Materials

|                   |            |
|-------------------|------------|
| Aniline           | 400 parts  |
| Hydrochloric acid | 157 parts  |
| Solvent           |            |
| CCl <sub>4</sub>  | 4000 parts |
| EtOH              | 80 parts   |
| Cl <sub>2</sub>   | 1060 parts |
3. Operating Parameters

Temperature: 16°C (60.8°F)

Pressure: not given

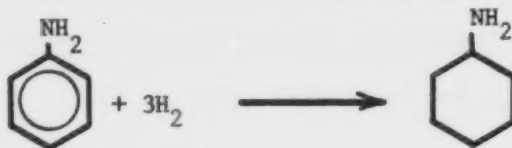
Catalyst: none

Reaction Time: 6 hours
4. Utilities - Not given
5. Waste Streams - Aniline, CCl<sub>4</sub>, EtOH, Cl<sub>2</sub>, and HCl traces should be present in the waste streams.
6. EPA Source Classification Code - None

7. Reference

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 415.

U.S. Patent 2,675,409 (Apr. 12, 1954).

Cyclohexylamine (from aniline)

1. Function - Cyclohexylamine is produced commercially by reducing aniline with hydrogen and a ruthenium or a Raney nickel catalyst. The reduction employing the ruthenium catalyst takes place at approximately  $220^\circ\text{C}$  and up to 3.45 - 6.90 MPa. As of 1964, only one U. S. plant (Abbott) produced cyclohexylamine by this process, but it accounted for 28% of the total U. S. production.
2. Input Materials  
Aniline  
Hydrogen  
Catalyst
3. Operating Parameters  
Temperature -  $220^\circ\text{C}$  ( $428^\circ\text{F}$ )  
Pressure - 3.45-9.60 MPa (34-94.7 atm)  
Catalyst - Raney nickel or ruthenium compound
4. Utilities - Not given
5. Waste Streams - Possibly excess hydrogen and some aromatics may be given off by the process.
6. EPA Source Classification Code - None

7. References

Astle, M. J., Industrial Organic Nitrogen Compounds, Rheinhold Publishing Co., New York, N.Y., 1961, p. 31.

Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4, (1972), p. 514.

Hahn, A. V., The Petrochemical Industry: Markets and Economics, McGraw-Hill Publishing Co., New York, N.Y., 1970, p. 431, 432.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 125.

Benzenesulfonic Acid

1. Function - Three basic methods have been used to produce benzenesulfonic acid: sulfuric acid, oleum, and sulfur trioxide. Sulfur trioxide is considered to be the effective sulfonating agent regardless of the sulfur reactant used.

Sulfonation with sulfuric acid

- a) Batch process - Benzene and sulfuric acid monohydrate are added to a sulfonator with agitation over a one hour period at an initial temperature of  $75^\circ\text{C}$ . The mixture is then heated to  $105^\circ$  for an hour and then held there for four hours.
- b) Continuous process - Sulfuric acid is fed continuously to the sulfonator concomitantly with benzene which has been previously fed through a vaporizer-superheater. The reaction mass flows to the top of a plate column which acts as a second sulfonator. This stream passes downward countercurrent to another stream of benzene vapor. A seven-stage reactor operating at  $180^\circ\text{C}$  and a molar ratio of benzene to sulfuric acid of 10:1, has a residence time of 1.5 hr. The benzenesulfonic acid is discharge from the bottom of the tower while the benzene vapor and water are released at the top and collected in a condenser. The benzene is separated, dried, and reused.

Sulfonation with oleum

Liquid benzene is charged to a presulfonator and 9.5% oleum is fed in over a period of time, the temperature being controlled by the rate of

addition of oleum. The reaction mass is then pumped to the vapor-feed sulfonators and raised to reaction temperature,  $-100^{\circ}\text{C}$ .

Benzene vapor is fed in until the desired residual-acid level is attained. The reaction mass flows from the bottom of the reactor to storage. The excess benzene and water of reaction is scrubbed with caustic to remove acids and is then condensed; the benzene is dried and returned to the process.

#### Sulfonation with sulfur trioxide

Benzene is allowed to react with sulfur trioxide in liquid sulfur dioxide at  $-90^{\circ}\text{C}$ . The liquid sulfur dioxide is evaporated until a temperature of  $10-20^{\circ}\text{C}$  is attained at which point benzene is added and the temperature is allowed to rise to  $50-70^{\circ}\text{C}$ . The sulfur dioxide is removed by an air stream.

In each process the benzenesulfonic acid can be crystallized from the sulfonation mass by cooling to  $-10^{\circ}\text{C}$  ( $13^{\circ}\text{F}$ ) to give a low recovery of solid sulfonic acid.

## 2. Input Materials

### Sulfonation with sulfuric acid

a) Batch process: benzene - 0.49 kg/kg product

$\text{H}_2\text{SO}_4$  - 1.24 kg/kg product

b) Continuous process - benzene - 4.94 kg/kg product

sulfuric acid - 0.62 kg/kg product

### Sulfonation with oleum

Benzene

Oleum



Sulfonation with sulfur trioxide

Benzene - 0.49 kg/kg product

Sulfur trioxide - 0.62 kg/kg product

Liquid sulfur dioxide

Sulfur trioxide: sulfur dioxide = 1.8

3. Operating Parameters

Sulfonation with sulfuric acid

a) Batch process - temperature - 65-105°C (149-221°F)

pressure - not given

b) Continuous process - temperature - 180°C (356°F)

pressure - not given

Sulfonation with oleum

temperature - ~100°C (-212°F)

pressure - not given

Sulfonation with sulfur trioxide

Temperature: Stage 1 - 9°C (48°F)

Stage 2 - 10-20°C (50-68°F)

Stage 3 - 50-70°C (122-158°F)

Pressure: not given

Purification

Temperature - -10°C (14°F)

4. Utilities

Not given

5. Waste Streams - possible benzene vapors from leaks in system; diphenyl sulfone;  $\text{H}_2\text{SO}_4$ .

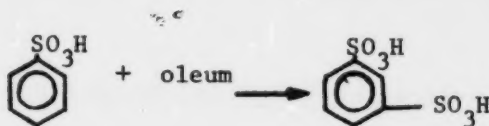
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1963), p. 403,404.

U. S. Patent 2,125,189 (July 26, 1938).

U. S. Patent 2,798,089 (July 2, 1957).

Benzenedisulfonic Acids

1. Function - The meta isomer of benzenedisulfonic acid is produced from the benzenesulfonic acid by direct sulfonation. In this process the monosulfonic acid is reacted with 65% oleum at 30-85°C for 6.5-7.5 hr. The para isomer cannot be produced by direct sulfonation. However, it is produced from the disodium salt of m-benzenedisulfonic acid by heating at 300°C under pressure, with a metal catalyst.

2. Input Materials

m-Benzenedisulfonic acid

Benzenesulfonic acid

65% oleum

p-Benzenedisulfonic acid

m-Benzenedisulfonic acid disodium salt

Catalyst

3. Operating Parameters

Benzenedisulfonic acid: temperature - 30-85°C (86-185°F)

pressure - not given

p-Benzenedisulfonic acid - temperature - 250-600°C (482-1112°F)

pressure - 405 kPa (4 atm)

catalyst - heavy metal (Hg, Ca)

4. Utilities

Not given

5. Waste Streams - none identified but suspect  $\text{SO}_3$ ,  $\text{SO}_2$ , benzene vapors.

6. EPA Source Classification Code - None

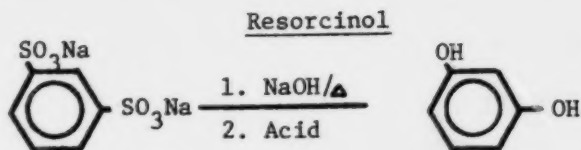
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 406.

Gilbert, E. E., Sulfonation and Related Reactions, Interscience Publishers,  
New York, N.Y., 1965, p. 69.

Groggins, P., Unit Processes in Organic Synthesis, 5th Ed., McGraw-Hill  
Book Co., Inc., New York, N.Y., 1958, p. 312.

British Patent 834,251 (May 4, 1960).



1. Function - Resorcinol can be made from m-benzenedisulfonic acid.

The final sulfonation mixture from the manufacture of m-benzenedisulfonic acid is treated with 0.9 equivalents of a solution of sodium sulfite under agitation. The mixture is sent to another vessel containing a suspension of excess calcium carbonate in water, and the mixture is filtered. The filtrate, containing sodium sulfonate and calcium sulfonate, is treated with 0.1 equivalent of sodium carbonate. After the calcium carbonate precipitate is removed on another filter, the sodium m-benzenedisulfonate is obtained as a 20% solution. A steam heated drum dryer then concentrates the solution to 50%.

This dry salt is mixed by stirring with flaked caustic soda and fused at 360°C (679°F) in a gas-heated, sealed, cast-iron vessel. After cooling the mass is taken up in water. The solid sulfite is separated by filtration and the filtrate is acidified with hydrochloric acid. The free resorcinol is then extracted with diethyl ether in a continuous extractor.

2. Input Materials

m-Benzenedisulfonic acid - 2.17 kg (lb)/kg (lb) product

Sodium sulfite

Calcium carbonate

Water

Sodium carbonate

Caustic soda - 3.6 kg (lb)/kg (lb) product

Hydrochloric acid

Diethyl ether

3. Operating Parameter

Temperature: 360°C (679°F)

Pressure: not given

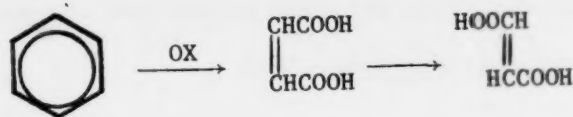
4. Utilities - Not given

5. Waste Streams - Various salts should be present in the sludge  
and SO<sub>x</sub> should be emitted to the air.

6. EPA Source Classification Code - None

7. Reference

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Inter-  
science Publishers, New York, N.Y., Vol. 11 (1966) p. 475.

Fumaric Acid (from benzene)

1. Function - Fumaric acid is manufactured from maleic acid and by direct oxidation of benzene without isolating the maleic acid formed. Air and benzene are mixed and passed into a converter where oxidation takes place in the presence of  $V_2O_5 + P_2O_5$  proprietary catalyst. The temperature of the reaction is kept near 400-450°C by heat-transfer coolants.

When fumaric acid is the desired product, the effluent gases from the converter may be scrubbed with hydrochloric acid to effect the isomerization. Ammonium persulfate - ammonium bromide mixtures and 10-20% HCl may also be used to catalyze the isomerization of maleic acid to fumaric acid.

The fumaric acid precipitates from the aqueous medium and may be purified by recrystallization or sublimation.

2. Input Materials

Benzene - 0.71 kg/kg product

Air

3. Operating Parameters - Converter:

Temperature - 400-450°C (752-842°F)

Pressure - 101-446 kPa (1.0-4.4 atm)

Isomerization:

Temperature - -100°C (212°F)

Pressure - 101 kPa (1 atm)

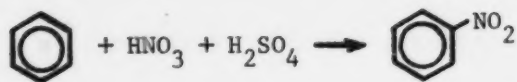
Catalyst - HCl



4. Utilities - Not given
5. Waste Streams - Waste water may contain unreacted maleic acid and dilute hydrochloric acid, and fumaric acid not recovered by crystallization.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 819-829.

A. L. Waddams, Chemicals From Petroleum, 3rd Ed., John Wiley & Sons, 1973,  
p. 224-225.

Nitrobenzene

1. Function - The usual method for the commercial manufacture of nitrobenzene is the direct nitration of benzene using mixed sulfuric and nitric acids. The reaction vessels are specially built cast-iron or steel kettles fitted with efficient agitators. The kettles are jacketed and generally contain internal cooling coils for proper temperature control of the strongly exothermic reaction. The batch equipment is normally sized for 454-680 kg quantities of benzene and operates on a time cycle of 2-4 hr.

In the typical batch process, the nitrator is charged with benzene and a heel of spent acid and the mixed acid (53-60%  $\text{H}_2\text{SO}_4$ , 32-39%  $\text{HNO}_3$  and 8%  $\text{H}_2\text{O}$ ) is added slowly below the surface of the benzene. Although the ratio of reactants is expressed in different ways from plant to plant, using this concentration of mixed acid the weight ratio of mixed acid to benzene is usually 2.5:1. The temperature of the reaction is maintained at 50-55° C by adjusting the rate of feed of mixed acid, the rate of heat exchange, and the agitation of the mixture, and it is usually raised to 90° C toward the end of the nitration to promote completion. The reaction mixture is then run into a separator where the spent acid settles out and is drawn off from the bottom of the unit. This spent acid is recovered or used as cycle acid to start subsequent runs after steam stripping to remove starting material. The crude nitrobenzene is drawn off the top of the separator and

can be used directly in the manufacture of aniline. If pure nitrobenzene is required, the product is washed with water and dilute sodium carbonate and then distilled.

Newer plants use a continuous process, as typified by the Biazzi process, for the production of nitrobenzene. The sequence of operations is essentially the same as in the batch process but the main differences are the use of smaller reaction vessels, lower nitric acid concentrations, and higher reaction rates. A typical 114 l continuous nitrator has a production capacity equal to a 568 l batch nitrator. Mixed acid of low nitric acid concentration and benzene sufficient to react with all of the nitric acid are mixed in the small stainless-steel nitrator fitted with a high-speed (600 rpm) agitator and a helical cooling coil. The reaction time is 15-20 min due to the rapid, efficient agitation. The reaction mixture is then drawn off from the side of the nitrator and allowed to separate for 10-20 min in a decanter. The washings are carried out in small vessels similar to the nitrator using high-speed mechanical agitation and are normally complete in 10 min.

2. Input Materials - Basis - 1 Mg Nitrobenzene

Benzene - 650 kg

Sulfuric Acid - 721 kg

Nitric Acid - 530 kg

Water - 109 kg

Sodium Carbonate - 10 kg

3. Operating Parameters

Temperature: 45 to 95° C (113-203°F)

Pressure: 101 kPa (1 atm)

Reaction time: 2-4 hrs.

4. Utilities

Cooling Water - quantity not given

Steam - quantity not given

Electricity - quantity not given

5. Waste Streams

Reaction section - absorber vent (air)

Benzene - 8.2 g/kg nitrobenzene

NO<sub>x</sub> - 0.09 g/kg nitrobenzene

Nitrobenzene - nil

Acid concentration section - absorber vent (air)

NO<sub>x</sub> - 0.16 g/kg nitrobenzene

Major wastewater streams would come from the nitrobenzene purification section for washing crude nitrobenzene and would contain benzene and nitrobenzene.

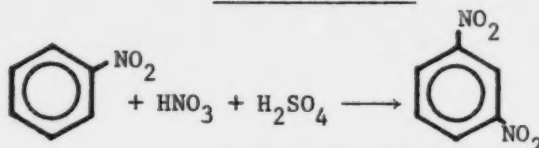
6. EPA Source Classification Code - None

7. References

Anon., "Air Pollution From Nitration Processes," prepared for Office of Air Programs, Environmental Protection Agency, Contract No. CPA 70-1, March 1972.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7," "Chemical Engineering," June 24, 1974, p. 154, 155.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y.; Vol. 13 (1967), p. 836, 837, 838.

Dinitrobenzene

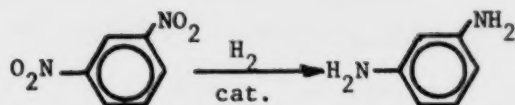
1. Function - Dinitrobenzene is produced by nitrating nitrobenzene with a hot mixture of sulfuric and nitric acids. The process is essentially identical with the process for nitrobenzene (Process No. 25) except that the temperature is higher (140-180°C). The product is purified by recrystallization.
2. Input Materials  
Nitrobenzene - 830 kg/Mg dinitrobenzene  
Sulfuric acid - 720 kg/Mg dinitrobenzene  
Nitric acid - 530 kg/Mg dinitrobenzene
3. Operating Parameters  
Temperature - 90-100°C (194-212°F)  
Pressure - 101 kPa (1 atm)
4. Utilities  
Steam - quantities are not given  
Cooling water - quantities are not given  
Electricity - quantities are not given
5. Waste Streams - Small quantities of NO<sub>x</sub> would be expected to be released to the air from reactor vents probably no more than 0.1 kg/Mg dinitrobenzene. Wastewater streams may be released from the purification step and may contain some spent acids, traces of mono-and dinitrobenzene, and some caustic soda used in the neutralization step.

6. EPA Source Classification Code - None

7. References

Groggins, P., Unit Processes in Organic Synthesis, 5th Edition,  
McGraw-Hill Book Co., New York, N.Y., 1958, p. 113-115.

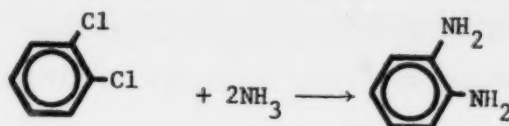
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4  
(1972), p. 551.

m-Phenylenediamine

1. Function - m-Phenylenediamine is produced by the catalytic reduction of m-dinitrobenzene with iron and HCl as in the case of p-phenylenediamine (Process No. 30).
2. Input Materials  
m-Dinitrobenzene  
Iron  
HCl
3. Operating Parameters - not given
4. Utilities - not given
5. Waste Streams - No specific information was available, but iron, iron sulfides, ammonia, and ammonium polysulfides should be present in the waste streams.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y. Vol. II (1963) p. 90.  
Ibid, Vol. 15 (1968) p. 216, 217.



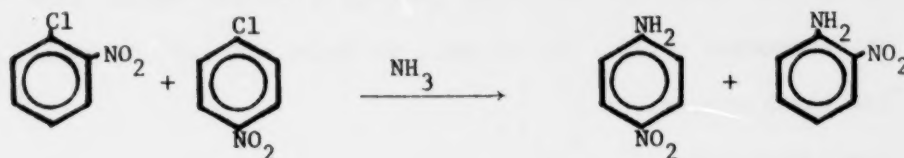
o-Phenylenediamine



1. Function - o-Phenylenediamine is produced by the action of ammonia on o-dichlorobenzene. The product is made in an agitated, induction heated, high pressure autoclave with 316 stainless steel lining and is purified by vacuum distillation.
2. Input Materials  
  
o-Dichlorobenzene  
  
Ammonia  
  
Catalyst ( $\text{Cu}^+$ )
3. Operating Parameters  
  
Temperature      1st Stage      180-190°C (356-374°F)  
                         2nd Stage      200-210°C (392-410°F)  
  
Pressure:      Not given  
  
Reaction time: 24 hrs
4. Utilities  
  
Not given
5. Waste Streams - Ammonia, hydrochloric acid, and copper chlorides should be present in the waste streams.
6. EPA Source Classification Code  
  
None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 361.

o- and p-Nitroanilines (from o- and p-chloronitrobenzenes)

1. Function o- and p-Nitroanilines are prepared commercially by ammonolysis of the appropriate chloronitrobenzene isomer. The process may be either batch or continuous.

The batch process will be described for the p-chloronitrobenzene but is identical for the o-isomer. Mixed isomers may be used since the physical properties of the isomers are sufficiently different so as to make separation of the o- and p-nitroanilines by either vacuum distillation or fractional crystallization entirely feasible.

In the batch method 1.892 m<sup>3</sup> (500 gal) jacketed autoclaves are used. Molten p-chloronitrobenzene (227 kg; 500 lbs) is added to 1180.9 kg (2600 lbs) of 26°Bé (28%) ammonia and heated over a 3 hr period to 175°C at a pressure of 3.65-4.00 MPa (530-580 psi). These conditions are maintained for 16 hrs and then excess ammonia is vented to an absorption system until the autoclave pressure reaches 1.38 MPa (200 psi). The charge is transferred to an ammonia still and then to wooden crystallizing tubs, where it cools and is then centrifuged. Operating yields of 95% are obtained and ammonia losses amount to only about 6%.

In the continuous process, preheated aqueous ammonia is forced through an inlet pipe to the bottom of a vertical reaction column

filled with p-chloronitrobenzene. The ammonia passes upward through an annular space and overflows through a central outlet pipe leading to an ammonia still. The product is drawn off and crystallized as in the batch process.

2. Input Materials

|                     |                      |                   |
|---------------------|----------------------|-------------------|
|                     | <u>Batch</u>         | <u>Continuous</u> |
| Chloronitrobenzene: | 227 kg (500 lbs)     | 150-200 parts     |
| Ammonia (26° Bé):   | 1180.4 kg (2600 lbs) | 900 parts         |

3. Operating Parameters

|              |               |                     |
|--------------|---------------|---------------------|
|              | <u>Batch</u>  | <u>Continuous</u>   |
| Temperature: | 175°C (347°F) | 225°C (437°F)       |
| Pressure:    | 3.65-4.00 MPa | 8.27 MPa (81.6 atm) |

4. Utilities - Not given

5. Waste Streams - Chlorinated nitrobenzenes and nitrophenols may be present in the sludge and some ammonia is lost to the air.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 352-353.

p-Phenylenediamine

1. Function - p-Phenylenediamine is produced by the catalytic reduction of p-nitroaniline with iron/HCl, iron/ammonium polysulfide/hydrogen, or iron/ferrous chloride.

A large wood vat is used in the process. Sufficient water is introduced to cover the agitator paddles (which operate at 40 rpm) and 453.6 kg (1000 lbs) iron borings are introduced. Then 45.4 kg (100 lbs) of 20° Be HCl is added, agitated and heated until a good paste of  $\text{FeCl}_2$  is produced. 340.2 kg (750 lbs) of p-nitroaniline is introduced and 226.8 kg (500 lbs) fine iron is added.

Just prior to filtration, the batch is made alkaline with soda ash, then sodium bisulfite/sodium sulfide are added to precipitate soluble iron salts and prevent subsequent oxidation. The mixture is filtered on a large plate-and-frame filter. The filtrate is concentrated then dried in two-stage vertical evaporators and film evaporators. About 37.2 kg (82 lbs) of crude product are obtained per 45.4 kg (100 lbs) p-nitroaniline reduced.

2. Input Materials - Basis: 1 kg (1b) product

|                |              |
|----------------|--------------|
| p-nitroaniline | 1.28 kg (1b) |
| Iron           | 1.60 kg (1b) |
| HCl (20° Be)   | 0.11 kg (1b) |

3. Operating Parameters

Temperature: 230-250°C (446-482°F)

Pressure: atmospheric

4. Utilities - Not given

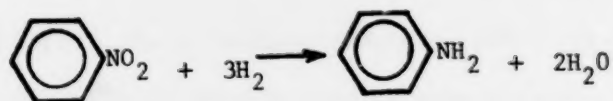
5. Waste Streams - No specific information is given, but iron, iron sulfides, ammonia and ammonium polysulfides may be found in the waste streams.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963) p. 87-90.

Ibid, Vol. 5 (1968) p. 217.

Aniline

1. Function - Aniline is produced commercially by the reduction of nitrobenzene. This is a continuous, vapor-phase process in which nitrobenzene is vaporized in a stream of hydrogen and fed to a fluidized bed reactor containing a hydrogenation catalyst. The catalyst can be copper carbonate, cuprammonium nitrate, alumina, or sulfides of nickel, molybdenum, or tungsten. The unreacted hydrogen is recycled to the reactor. Reactor effluent goes to a separator, where two phases are formed. The organic phase contains water, and is fractionated in a two-tower system to remove heavy residue water from the aniline product.

2. Input Materials - Basis - 1 metric ton aniline

|                                   |                                            |
|-----------------------------------|--------------------------------------------|
| Nitrobenzene - 1.35 Mg/Mg Aniline | 1350 kg (2,976 lbs)                        |
| H <sub>2</sub> - 65 kg/Mg Aniline | 81 m <sup>3</sup> (2,860 ft <sup>3</sup> ) |
| Copper carbonate                  | 0.7 kg (1.54 lbs)                          |

3. Operating Parameters

Temperature - 250-300°C (482-572°F)

Pressure - 238 kPa (2.35 atm)

Reaction time - 0.5 to 100 seconds

Catalyst - Cuprammonium nitrate or sulfide (nickel, molybdenum, tungsten) or alumina



#### 4. Utilities

Steam - quantity not given

5. Waste Streams - The separator aqueous layer, formed by the water of reaction, contains some aniline and may be discharged to the sewer. Sometimes this aniline is recovered by solvent extraction using the nitrobenzene.

Heavy residues and water from the fractionation tower may constitute an additional wastewater source.

|                  |   |                                         |
|------------------|---|-----------------------------------------|
| Flow             | - | 1.58 l/kg (190 gal/1000 lbs)            |
| COD              | - | 13,400 mg/l<br>21.2 g/kg (lbs/1000 lbs) |
| BOD <sub>5</sub> | - | 15 mg/l<br>0.02 g/kg (lbs/1000 lbs)     |
| TOC              |   | 12,150 mg/l<br>19.2 g/mg (lbs/1000 lbs) |

6. EPA Source Classification Code - None

#### 7. References

Hahn, A. V., The Petrochemical Industry: Market and Economics, McGraw-Hill Book Company, New York, N.Y., 1970, p. 503.

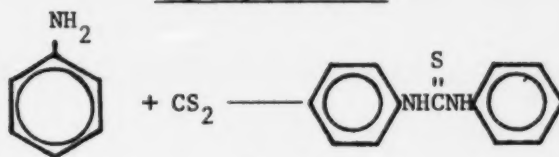
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 132.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 419.

Waddams, A. L., Chemicals From Petroleum, 3rd Ed., John Murray Ltd., London, Eng., 1973, p. 223.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition  
John Wiley and Sons, New York, N.Y., 1975, p. 113.

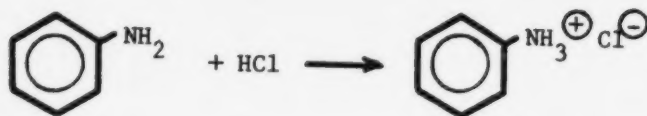
Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes  
Data Corp., Park Ridge, N.J., 1974, p. 76.

Diphenylthiourea

1. Function - Diphenylthiourea is produced by the reaction of aniline with carbon disulfide. A mixture of aniline, alcohol, carbon disulfide, and crystalline sulfur are heated to reflux for 5 to 6 hours. The mixture gradually solidifies. Excess carbon disulfide is distilled off. Excess aniline is removed with dilute hydrochloric acid. The diphenylthiourea is recrystallized from alcohol.
2. Input Materials  
Aniline  
Alcohol  
Carbon disulfide  
Sulfur (catalyst)
3. Operating Parameters  
Reflux 5 to 6 hours
4. Utilities - Not given
5. Waste Streams - Expect traces of carbon disulfide to be present in air due to this process. Waste waters may contain dilute acids and salts from washings, as well as aniline, and oxidation products of aniline.
6. EPA Source Classification Code - 3-01-034-01
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 414.

7. References (continued)

Houben Weyl, Methoden der Organischen Chemie, Vierte Auflage, Georg Thieme Verlag, Stuttgart, Bd. 9 (1955), p. 885.

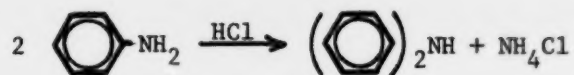
Aniline Hydrochloride

1. Function - Aniline hydrochloride is prepared by the direct reaction of aniline with hydrochloric acid. This is usually accomplished by two methods: a) by passing a stream of dry hydrogen chloride through an ethereal solution of aniline, or b) by neutralizing aniline at 100°C with concentrated hydrochloric acid. The product is purified by crystallization.
2. Input Materials  
Aniline - 0.704 kg/kg product  
HCl - 0.276 kg/kg product  
Ethyl ether
3. Operating Parameters
  - a) Temperature - ambient  
Pressure - atmospheric
  - b) Temperature - 100°C (212°C)  
Pressure - atmospheric
4. Utilities  
Not given
5. Waste Streams - No specific information available. An air emission containing traces of HCl and ether is possible from method (a). From method (b) aniline, HCl and traces of aniline hydrochloride are possible.

6. EPA Source Classification Code - 3-01-034-01

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 419.

Diphenylamine

1. Function - Diphenylamine is produced by heating aniline hydrochloride in an autoclave at 210-240°C and 730 kPa pressure. If a catalyst (0.5 weight % of amine) is used the aniline will condense with itself without the hydrochloride.

The product is then boiled with dilute hydrochloric acid to remove the unreacted aniline as the hydrochloride, and is distilled.

2. Input Materials

Aniline

Aniline hydrochloride

3. Operating Parameters

Temperature: 210-240°C (410-464°F)

Pressure: 730 kPa (7.2 atm)

4. Utilities

Steam: Quantities not given

5. Waste Streams - No information available but it is likely that a waste water stream would be generated containing distillation bottoms; small amount of hydrogen chloride or aniline may be given off.

6. EPA Source Classification Code - 3-01-034-01

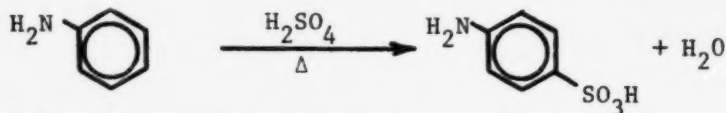
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963) p. 413, 420.



Ibid, Vol. 7 (1967), p. 40.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4  
(1972), p. 519.

Sulfanilic Acid

1. Function - Sulfanilic acid (p-aminobenzene sulfonic acid) is prepared by placing the sulfuric acid in an iron pan fitted with a stirrer and the aniline is run in over 3-4 hours. The reaction mass is stirred for another 3 - 4 hours and then transferred to a heated cast iron oven fitted with a chimney. The temperature is kept at 230°C until no further sulfur dioxide is emitted. After cooling, the crude product can be dissolved in dilute caustic soda solution, filtered from the carbonaceous material, boiled to expell any free aniline, then acidified to yield the free acid (98% yield).
2. Input Materials

|               |         |
|---------------|---------|
| Aniline       | 1374 kg |
| Sulfuric acid | 1597 kg |
3. Operating Parameters

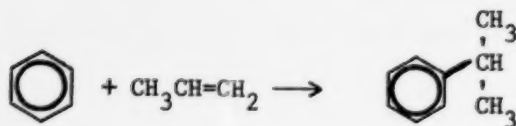
Temperature: 230°C (446°F)

Reaction Time: 6 - 8 hours (before baking)
4. Utilities - Not given
5. Waste Streams - Sulfur dioxide is emitted during the baking process and aniline vapors escape from the aniline recovery system. Some caustic soda sludge also should appear in the wastewater.
6. EPA Source Classification Code - None
7. References

Chemical Technology, Barnes and Noble Books, New York, N.Y., 1972, Vol. 4, p. 590.

Groggins, P., Unit Processes in Organic Synthesis, McGraw-Hill  
Book Co., New York, N.Y., 1958, p. 383.

Kirk-Othmer, Encyclopedia Of Chemical Technology, 2nd Ed., Inter-  
science Publishers, New York, N.Y., Vol. 2 (1963), p. 424.

Cumene (alkylation)

1. Function - Benzene is alkylated in the vapor phase with propylene in the presence of a phosphoric acid catalyst to yield cumene. An excess of benzene is maintained to suppress dialkylation, oligomerization and other side reactions.
2. Input Materials - Basis - 1 metric ton cumene  
Benzene: 800 kg (1,764 lbs)  
Propylene: 430 kg (948 lbs)
3. Operating Parameters  
Temperature: 250°C (482°F)  
Pressure: 689 kPa (6.80 atm)  
Flow rates: not given  
Equipment: chamber type reactor  
Catalysts: phosphoric acid on kieselguhr  
Catalyst Consumption: 1.667 m<sup>3</sup> cumene formed/kg catalyst
4. Utilities  
Not given
5. Waste Streams - The principal waste water streams from the manufacture of cumene results from the recovery of cumene from the process stream. This stream contains some 1-4% of the product stream. The quantity of water carrying the wastes depends largely upon the use of propane to control bed temperature.

6. EPA Source Classification Code - None

7. References

Brownstein, A. M., U.S. Petrochemicals - Technologies, Markets, and Economics, The Petroleum Publishing Company, Tulsa, Oklahoma, 1972.

"1969 Petrochemical Handbook," "Hydrocarbon Processing," Nov., 1969, p. 167.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollutational Problems Associated with Petrochemical Wastes," for FWPCA, Contract No. 14-12-451, Ada, Oklahoma, 1970.

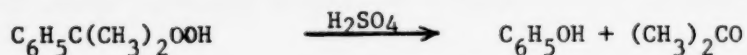
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 544, 545.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 892.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3," "Chemical Engineering," March 18, 1974, p. 91.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 294, 295.

Phenol, Acetophenone, and Acetone (from cumene via hydroperoxide)

1. Function - As of January 1, 1975, almost 91% of synthetic phenol capacity was based on the cumene peroxidation process. Cumene is oxidized to cumene hydroperoxide as described in Process No. 294 and fed to an acidifier containing 5-25% sulfuric acid. The reactants are agitated at 45-65°C until the cumene hydroperoxide is cleaved to phenol and acetone.

After the reaction, the mixture is phase-separated to yield an oil layer containing cumene, phenol, acetone,  $\alpha$ -methylstyrene (1.5%), acetophenone (0.8%), and tars. These are separated from each other by distillation or by a combination of distillation and extraction. The  $\alpha$ -methylstyrene can be hydrogenated to cumene and recycled or recovered as a by-product. Acetophenone is recovered as a by-product. Unconverted cumene can be removed after the oxidation step or recovered in the final distillation.

2. Input Materials

Cumene hydroperoxide (from cumene - 1.42 kg/kg phenol)  
Sulfuric acid

3. Operating Parameters

Temperature: 45 - 65°C (113-149°F)  
Pressure: not given

4. Utilities\* - Basis: 1.44 kg/sec capacity (100 M lb/yr)

Cooling water -  $1.99 \text{ m}^3/\text{sec}$  (1.89 M gph)  
Steam - 14.2 kg/sec (113,000 lb/hr)  
Electricity - process - 1778.4 MJ (494 KW)  
                  utilities - 626.4 MJ (174 KW)  
Nitrogen -  $393 \text{ scm}^3/\text{sec}$  (50 scfh)

5. Waste Streams\*

Crude phenol surge vessel (water)

Cumene - trace  
Acetone - 0.46 kg/Mg phenol  
Phenol - 0.08 kg/Mg phenol

Single vessel mesityl oxide column (water)

Mesityl oxide plus other contaminants - 19.9 kg/Mg phenol

Hydrogenation column vent (air)

Hydrogen - 15.0 g/Mg phenol  
Carbon monoxide - 20.0 g/Mg phenol

Catalytic columns vent (air)

Methylstyrene - trace  
Carbon monoxide - 0.22 kg/Mg phenol  
Phenol - 1.48 kg/Mg phenol

Steaming column vent (air)

No data given (assume phenol to be the major pollutant) - 0.5 -1.0  
kg/Mg product

Evaporator residue (solid)

Acetophenone - 1.9 kg/Mg phenol  
Phenol - 0.75 kg/Mg phenol  
Polymeric matter - 110 kg/Mg phenol  
Cumylphenol - 0.85 kg/Mg phenol

6. EPA Source Classification Code 3-01-034-01

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 1", "Chemical Engineering", January 21, 1974, p. 130.

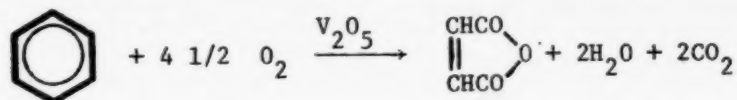
Ibid., Part 8, July 22, 1974

\* Includes Process No. 36



"1973 Petrochemical Handbook Issue", Hydrocarbon Processing,  
November, 1973, p. 158.

Hedley, W. H., et al., Potential Pollutants from Petrochemical  
Processes, Technomic Publishing Co., 1975.

Maleic Anhydride (from benzene)

1. Function - A stream of benzene is vaporized in a mixer with an optimum amount of air. The vapors from the mixer pass then through a converter containing vanadium pentoxide on an inert carrier. Tubes that circulate mercury or fused salts serve to remove the heat of the reaction and thus control the temperature between 400 to 450°C.

The reaction gases from the reaction pass through a vapor cooler and then to a condenser. The bulk of the maleic anhydride is recovered in the condensers and contains some maleic acid. This is converted to the anhydride by vacuum or azeotropic distillation (using hydrocarbons).

As of 1973 all the maleic anhydride intentionally manufactured in the United States is produced via the oxidation of benzene. It is also obtained as a by-product in the manufacture of phthalic anhydride. Use of C<sub>4</sub> hydrocarbons as feedstock is planned by different companies. One plant (Ashland) is designed to use benzene but can be adapted to butane feedstock.

2. Input Materials - Basis - 1 metric ton maleic anhydride

Air - 37.48 Mg/Mg (74,963 lb/ton) product - 15,600-21,750 m<sup>3</sup>

Benzene - 1.872 Mg/Mg (3,745 lb/ton) product - (550,909-768,094 ft<sup>3</sup>)

Sodium perborate - 10.2 kg/Mg (20.2 lb/ton) product - 1,340 kg (2,954 lbs)

Demineralized water - 23.66 kg/Mg (47.31 lb/ton) product

### 3. Operating Parameters

Temperature - 400-450°C (752-842°F)

Pressure - 101 kPa (1 atm)

Contact time - ~0.1 sec.

Catalysts -  $V_2O_5 + MoO_3$  (on aluminum turnings or diatomaceous earth)

### 4. Utilities

Basis - 13.6 Gg/yr (30 M lb/yr) capacity

#### Water

Coolant - 88 dm<sup>3</sup>/s (1,400 gpm)

Makeup cooling - 1.8 dm<sup>3</sup>/s (28 gpm)

Boiler makeup - <63 cm<sup>3</sup>/s (<1 gpm)

#### Steam

Generated by reactor - 12.6 Mg/hr (27,800 lb/hr)

Required - 1.3 Mg/hr (2,800 lb/hr)

Net - 11 Mg/hr (25,000 lb/hr)

Electricity - 11 GJ (3,000 kWh/hr)

Nitrogen - 6.2 m<sup>3</sup>/hr (200 scfh)

### 5. Waste Streams

Recovery section - scrubber (air)

Benzene - 131 kg/Mg (262 lb/ton product)

Carbon monoxide - 780 kg/Mg (1,560 lb/ton) product

Maleic acid - trace

Purification section - anhydride vacuum column-bottoms (water)

Maleic anhydride - 3.8 kg/Mg (7.5 lb/ton)

High boilers (tar, fumaric acid, chromogenic compounds) - 27 kg/Mg (53 lb/ton)

5. Waste Streams (continued)

Purification section - anhydride vacuum column-overhead (water)

Maleic acid - 0.6 kg/Mg (1.2 lb/ton)

6. EPA Source Classification Code - None

7. References

Morse, Park L., "Maleic Anhydride", Report No. 46, Stanford Research Research Institute, Menlo Park, California, 1969.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollutional Problems Associated with Petrochemical Wastes", Report of FQPCA, 1970.

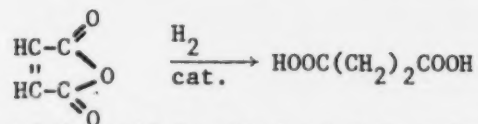
Austin, G. T., "Industrially Significant Organic Chemicals - Part 7," "Chemical Engineering," June 24, 1974, p. 150, 151.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 828, 829.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, Interscience, New York, N.Y., 1975, p. 514-8.

Chemical Week, May 9, 1973, p. 33.

Chemical Week, February 5, 1975, p. 13.

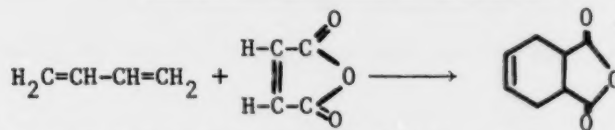
Succinic Acid (from maleic anhydride)

1. Function - Succinic acid is obtained from maleic anhydride by hydrogenation. Molten maleic anhydride is charged to a hydrogenator. The vessel is purged and filled with hydrogen. A Raney-nickel catalyst is added as a slurry, agitation started, and the temperature is raised to 130 - 140°C (265 - 283°F). Hydrogen pressure of 17 megapascals (168 atm) is maintained for 4 - 6 hours. The product is then removed and distilled in two stages. The first removes any unreacted maleic anhydride under a vacuum as overheads. The second stage fed by the bottoms from the first removes the succinic acid under a vacuum as distillate overhead. The product is condensed, dried and sold as a white flake.
2. Input Materials  
Maleic anhydride  
Catalyst  
Hydrogen
3. Operating Parameters  
Temperature: 130 - 140°C (265 - 283°F)  
Pressure: 17 MPa (167.8 atm)  
Reaction Time: 4 - 6 hours
4. Utilities - Not given
5. Waste Streams - The maleic anhydride and some catalyst may be present in the waste streams.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, Second Edition,  
Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 143.

Tetrahydrophthalic Anhydride

1. Function - cis-1,2,3,6-Tetrahydrophthalic anhydride is manufactured by the Diels-Alder reaction. 1,3-Butadiene reacts with maleic anhydride in benzene at room temperature (12 hours) and is then heated to 100°C for five hours in an autoclave. The product is crystallized from benzene-ligroin.

2. Input Materials - Basis - 1 kg (1b) product

|                  |                             |
|------------------|-----------------------------|
| 1,3-Butadiene    | 0.458 kg (1b)               |
| Maleic anhydride | 0.715 kg (1b)               |
| Benzene          | 1.14 l inside reaction vat  |
|                  | 1.43 l outside reaction vat |

3. Operating Parameters

Temperature: 20°C (67°F)

Pressure: not given

4. Utilities - not given

5. Waste Streams - Possible benzene emissions from purification of product are the only wastes from this reaction since the yield is quantitative.

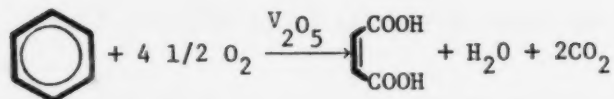
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y. Vol. 12 (1967) p. 825.

Adams, R., Organic Reactions, John Wiley and Sons, New York, N.Y., Vol. 4 (1948), p. 41.



Maleic Acid

1. Function - Maleic acid is produced in conjunction with the manufacture of maleic anhydride (see Process 38). If maleic acid is to be the sole product, the gases from the reactor are absorbed in water to give a 40% solution. The solution is purified with activated carbon, concentrated, and crystallized.

A small amount of maleic acid is also obtained as a by-product in the manufacture of phthalic anhydride.

2. Input Materials

Benzene

Air

Water

3. Operating Parameters

Temperature: 400 - 500°C (752-932°F)

Pressure: 101 kPa (1 atm)

Contact time: ~0.1 sec

Catalyst:  $\text{V}_2\text{O}_5$

4. Utilities

Similar to those in Process

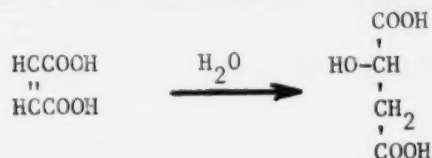
5. Waste Streams - Benzene vapors not recycled and maleic acid not recovered by crystallization; CO, CO<sub>2</sub> and hydrocarbons.

6. EPA Source Classification Code - None

7. References

Lowenheim, F. A., Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 514-518.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 829.

Malic Acid (from maleic acid)

1. Function - R, S -Malic acid can be produced from maleic acid by hydration at elevated temperatures and pressures in the presence of catalysts. The reactors need to be corrosion-resistant.

The vapors from the gas-phase oxidation of benzene are dissolved in water to give a solution of maleic acid. The solution is treated 4 to 5 hr with oxygen at 70° C. After preliminary purification the solution passes through three Ti reactors at 185° C and 15 kg/cm<sup>2</sup>, with residence time of 2.5, 1.6, and .85 hr. The resulting solution is cooled to 40° C to remove fumaric acid. The crude malic acid is purified further by recrystallization. Removal of traces of fumaric acid and mineral ions (Fe, Cu, Ca, Mg, Al) may be accomplished by the use of ion-exchange resins.

2. Input Materials

Maleic acid

Water

Oxygen

Catalyst - Co

3. Operating Parameters

Temperature - 185° C (365°F)

Pressure      15 kg/cm<sup>2</sup> (1.47 MPa)

4. Utilities - Not given.

5. Waste streams - Waste waters essentially free of traces of by-products and mineral ions with use of ion exchange resins.

6. EPA Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Vol. 12, Interscience Publishers, New York, N.Y., 1967 p. 843-846.

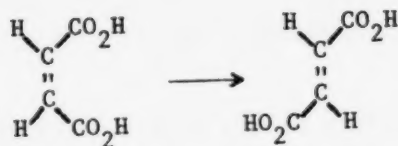
Allied Chemical Corp. Neth. Appl. 6,516, 753, July 1, 1966.

(C.A. 65-P16867d)

Ahlgreen, C. R. (to Allied Chemical Corp.) Belg. 670, 932,

January 31, 1966 (C.A. 65-P13551C)

Allied Chemical Corp. Neth. Appl. 6,600,665 (1966). (C.A. 65-  
16867).

Fumaric Acid (from maleic acid)

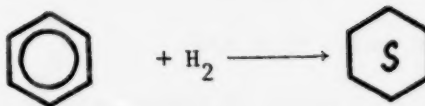
1. Function - Fumaric acid is manufactured by two main methods: (1) directly from benzene or (2) from maleic acid. The process employing benzene is discussed under Process No. 38. The process using maleic acid feed uses amine bases, mercaptans, heavy metal salts, mineral acids, disulfides, and other materials as catalysts. In common use are ammonium persulfate-ammonium bromide mixtures and 10 - 20% HCl. The conversion is carried out at atmospheric pressure at 40 - 60°C (103 - 139°F). Fumaric acid precipitates from the aqueous medium and after separation is dried and purified by recrystallization or sublimation.
2. Input Materials  
Maleic acid  
Catalyst
3. Operating Parameters  
Temperature: 40 - 60°C (103 - 139°F)  
Pressure: 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Unreacted maleic acid, HCl, and catalyst should be present in the waste streams.
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 6," "Chemical Engineering," May 27, 1974, p. 102.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 829.

Sittig M., Chemicals from Aromatics, Noyes Development Corp., Park Ridge, N.J., 1966, p. 28, 29.

Cyclohexane

1. Function - Cyclohexane (35%) is produced from benzene by a liquid phase hydrogenation process. The reaction occurs at 220°C (428°F) and 3.5 MPa (34.5 atm) using a platinum or Ni catalyst containing a small amount of lithium salt supported on alumina. A typical plant incorporates several reactors for a stepwise operation. The recycled cyclohexane, hydrogen and make-up hydrogen pass through the beds in series, while the benzene passes through in parallel. This reduces the quantity of recycle cyclohexane and excess hydrogen required. The recycle cyclohexane absorbs the heat of hydrogenation, thus avoiding high bed temperatures and possible isomerization.
2. Input Materials - Basis - 1 metric ton cyclohexane  
Benzene - 0.98 kg (lb)/kg (lb) product 93.5 kg (2,061 lbs)  
Hydrogen - 65 kg (143 lbs)  
Catalyst - small
3. Operating Parameters  
Temperature - 220°C (428°F)  
Pressure - 3.5 MPa (34.5 atm)
4. Utilities - 45 M kg/yr (100 M lbs/yr), 350 days/yr  
Electricity - 250 kW  
Steam - kg/hr (lbs/hr) - consumed [4.2 MPa = 41.5 atm] - 4994 (11,000)  
generated - (1.2 MPa 11.8 atm) 6350 (14,000)



Cooling water - ( $\Delta T = 15^{\circ}\text{C}$ )  $0.039 \text{ m}^3/\text{s}$  (618 gpm)

HP steam required - 2.3 t/hr

LP steam produced - 11.8 t/hr

5. Waste Streams - Outside of spent caustic wash ( $2 \times 10^{-6} \text{ m}^3/\text{kg} = 0.24 \text{ gal}/10^3 \text{ lbs}$ ), the only major source of wastewater is the cooling water which amounts of 171-1717  $\text{g}/\text{m}^3$  (200-2,000 gal/ton) of cyclohexane and which may contain 50-200 mg/l of COD. In the aromatics extraction, there are two major sources of wastewater: the extract water washing which contains aromatic hydrocarbons and the wastes from solvent regeneration which contain appropriate solvents. Both wastes may be minimized by the use of stripping columns.

Purge gas from the hydrogenation reactor may contain benzene, hydrogen, sulfur, and carbon monoxide.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3," "Chemical Engineering," March 18, 1974, p. 91,92.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 679.

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 201.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Company, Westport, Conn., 1975.

7. References (Continued)

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973, p. 116,117.

Sittig, M., Pollution Control in the Organic Chemical Industry,

Noyes Data Corp., Park Ridge, N.J., 1974, p. 116.

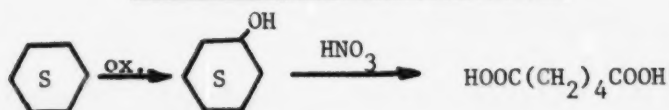
Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,

John Wiley and Sons, New York, N.Y., 1975, p. 299.

Sittig, M., Chemicals from Aromatics, Noyes Development Corp., Park

Ridge, N.J., 1966, p. 4-9.

U.S. Patent 3,254,134 (May 31, 1966).

Adipic acid (from cyclohexane)

1. Function - Adipic acid is obtained from cyclohexane in a two stage process. First stage involves air oxidation of cyclohexane to an alcohol-ketone mixture. The reaction carried out at 125-160°C and 404 kPa (4 atm.) uses a cobalt naphthenate or cobalt stearate catalyst.

The second stage oxidizes the alcohol-ketone mixture to adipic acid using 40 to 50% nitric acid. The reaction carried out at 50 - 150°C (122 - 302°F) and 345 - 1724 kPa (3.4 - 17.0 atm.) uses a catalyst made of ammonium meta-vanadate and copper.

The liquid product from the reactor is air stripped to remove nitrous oxides and steam distilled to remove nitric acid and low-boiling organics as overhead. The still bottoms are cooled to 40 - 50°C (104 - 122°F) and the adipic acid crystallizes. The crystals are dried to produce the adipic acid.

Adipic acid may also be made by air oxidation of cyclohexane.

2. Input Materials

Basis - 1kg (1b) adipic acid

- 1) Cyclohexane - 1.65 kg (1g)

Air - variable

Catalyst - 0.1 g (0.0001 lb)

- 2) Nitric acid - 6.75 kg (1b)

Catalyst: Copper - 15 g (0.015 lb)

Ammonium meta-vanadate 5 g (0.005 lb)

3. Operating Parameters

1) Temperature: 125 - 160°C (257 - 320°F)

Pressure: 404 kPa (4atm)

2) Temperature: 50 - 150°C (122 - 302°F)

Pressure: 345 - 1724 kPa (3.4 - 17.0 atm)

Reaction time: 1 hour

4. Utilities - Not given

5. Waste streams - Air pollution - nitrous oxides and nitrogen dioxides from oxidizer; particulates from vent on product drying.

Water pollution - metallic catalyst residues and by-product organic acids.

6. EPA Source Classification Code - None

7. References

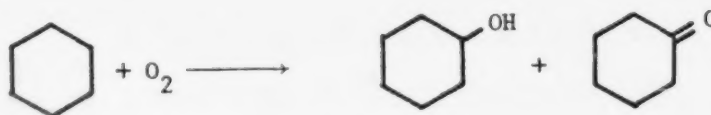
Austin, G.T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 131.

Hedley, William H., et. al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Company, Westport, Conn., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963) p. 411.

Sittig, M., "Pollution Control in the Organic Chemical Industry," Noyes Data Corporation, Park Ridge, New Jersey. 1974. p. 67, 68, 69, 70, 71.

Faith, W.L., et. al., Industrial Chemicals, 3rd Ed., John Wiley and  
Sons, New York, N.Y., 1965, p. 46, 47.

Cyclohexanol And Cyclohexanone (KA oil)

1. Function - Cyclohexanol is produced by oxidizing cyclohexane with air in the presence of a catalyst. The basic process takes place in the liquid phase by means of an oxygen-containing gas at a temperature of 120-250°C (248-482°F) and a pressure high enough to keep the cyclohexane from vaporizing, and in the presence of an oxidation catalyst such as cobalt naphthenate. This reaction produces a mixture of cyclohexanol and cyclohexanone. The two can be separated by conventional vacuum-fractionating techniques.

A second technique which can be used if cyclohexanol is the desired product is the oxidation of cyclohexane over a boric acid catalyst. This process can result in alcohol-to-ketone yields as high as 10 to 1.

2. Input Materials - Basis - 1 metric ton cyclohexanone

Cyclohexane - 1010 kg (2227 lbs)

Air - variable

Catalyst (Mn + Co acetates)

Metaboric acid - 5 kg (11 lbs)

Zno - 0.75 kg (1.65 lbs)

3. Operating Parameters

Temperature - 120-250°C (248-482°F)

Pressure - Not given

4. Utilities - Not given

5. Waste Streams - Cyclohexane from separation process; residual crude from distillation; catalyst salts.

6. EPA Source Classification Code - None

7. References

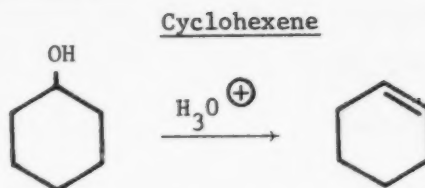
"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973  
p. 118.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3,"  
"Chemical Engineering," March 18, 1974, p. 92.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 684-686.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 304,305.





1. Function - Cyclohexene can be manufactured by:
  - a) direct dehydration of cyclohexanol in presence of a catalyst;
  - b) dehydrohalogenation of the chlorocyclohexane or bromocyclohexane formed by halogenating cyclohexanol or cyclohexane.

2. Input Materials

Dehydration:

Cyclohexanol

Catalyst ( $\text{Al}_2\text{O}_3$ ,  $\text{H}_3\text{PO}_4$ )

Dehydrohalogenation

Chloro- or bromo-cyclohexane

(from cyclohexanol or cyclohexane)

Dehydrohalogenating agent

3. Operating Parameters

Dehydration

(with  $\text{H}_3\text{PO}_4$ )

Initial temperature - 165-170°C

Final temperature - 200°C

Pressure - 101 kPa (1 atm)

Dehydrohalogenation

Catalyst - Zeolite impregnated with alkali oxide, or charcoal  
impregnated with  $\text{CuCl}_2$

3. Operating Parameters (continued)

Temperature - 150-250°C

Pressure - not given

(nitrogen atmosphere)

Catalyst-cyclic amidine in  $(\text{CH}_3)_2\text{SO}$

Temperature - 80-90°C

Pressure - not given

4. Utilities - not given

5. Waste Streams - In some continuous processes the  $\text{Br}_2$  used to halogenate cyclohexane is recovered by absorbing the  $\text{HBr}$  in magnesia and oxidizing the resulting mass at 300°C.

6. EPA Source Classification Code - None

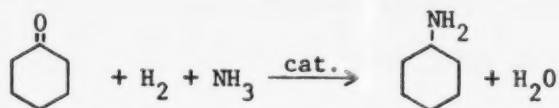
7. References

Houben Weyl - Methoden der Organischen Chemie, Vierte Auflage Bd. 5, T. 1b, George Thieme Verlag Stuttgart, 1972, p. 71, 160, 176-179.

French Patent 385,650 (January 15, 1965).

Belgian Patent 632,808 (November 25, 1963).

Organic Synthesis, John Wiley and Sons, New York, N.Y., Collective Vol. 2 (1943), p. 152.

Cyclohexylamine (from cyclohexanone)

1. Function - Cyclohexylamine is manufactured by the reductive amination of cyclohexanone. This can be done in two ways both employing the same basic reaction with different operating parameters.

Process #1

Cyclohexanone is reduced with hydrogen in the presence of ammonia. A nickel catalyst supported on kieselguhr is activated by hydrogen at 427°C and used to promote the reaction which proceeds at 200°C and 31,088 kPa. One hundred percent conversion is achieved containing 81 wt.% cyclohexylamine.

Process #2

In this process cyclohexanone is reduced with hydrogen in ammonia over nickel. The operating parameters are at least 40°C and 769,359 kPa. Following the reaction the material is azeotroped with C<sub>6</sub>H<sub>6</sub> then distilled to give a 99% pure product.

3. Input Materials

Process #1

Cyclohexanone - 1.23 kg/kg product

Ammonia - not given

Hydrogen - not given

Catalyst - not given

Process #2

Cyclohexanone - 1 kg/kg product

Ammonia - 0.65 kg/kg product

Hydrogen - 0.04 kg/kg product

Catalyst - 0.11 kg/kg product

Benzene

3. Operating Parameters

Process #1

Temperature: 200°C (392°F)

Pressure: 31.088 MPa (306.8 atm)

Catalyst: nickel

Process #2

Temperature: 40°C (104°F)

Pressure: 769.359 MPa (7,593 atm)

Catalyst: nickel

4. Utilities

Not given

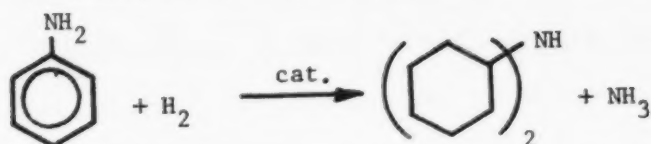
5. Waste Streams - possible hydrocarbon emissions from leaks in system;  
some nickel compounds and benzene may leak out.

6. EPA Source Classification Code - None

7. References

French Patent, 1,446,554 (July 22, 1966).

British Patent, 1,050,589 (December 7, 1966).

Dicyclohexylamine (from aniline)

1. Function - Dicyclohexylamine is best prepared by the vapor phase catalytic hydrogenation of aniline over a nickel catalyst. The aniline (15 g/hr) is evaporated into a circulating hydrogen stream (425 l/hr) and the resulting mixture introduced into a reaction zone packed with a nickel-on-pumice (7 parts) catalyst. The vapors leaving the reaction zone are cooled to about 45°C, liquifying the dicyclohexylamine and a small amount of cyclohexylamine. The uncondensed vapors are cycled to the reactor after removing part of the ammonia and adding fresh aniline and hydrogen.

Dicyclohexylamine may also be prepared from cyclohexanone (via the cyclohexylamine produced) as in Process No. 48 using a different set of operating parameters (101 kPa and 260°C).

2. Input Materials - Basis - 1 kg dicyclohexylamine

Aniline, g 1,250

Catalyst: 7 parts nickel-on-pumice

3. Operating Parameters

Aniline feed, g/hr 15

Hydrogen feed, l/hr 425

Temperature - not given

Pressure - not given

4. Utilities

Not given

5. Waste Streams - Basis - 1 kg dicyclohexylamine

There should be some aniline, hydrocarbons, and ammonia given off in addition to the 125 g cyclohexylamine and 11.4 g cyclohexanol.

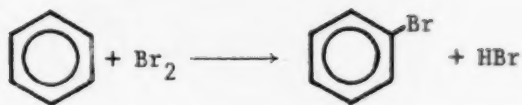
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 416.

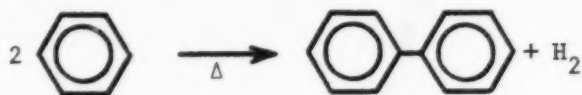
German Pat. 805,518 (May 21, 1951).

U.S. Pat. 3,551,486 (December 29, 1970).

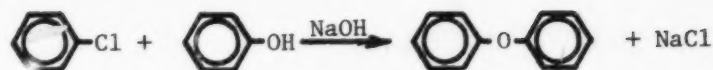
Bromobenzene

1. Function - Bromobenzene can be manufactured from benzene by reacting dry bromine with benzene in the presence of a catalyst such as Fe. This reaction takes place at 101 kPa (1 atm) and 80-100°C (175-212°F). Separation involves scrubbing to remove impurities and fractionating.
2. Input Materials  
Bromine  
Benzene  
Catalyst
3. Operating Parameters  
Temperature - 80-100°C (175-212°F)  
Pressure - 101 kPa (1 atm)  
Catalyst - Fe
4. Utilities - Not given
5. Waste Streams - Benzene from scrubbing and stripping operations, spent scrubbing sludge; unreacted iron and bromine.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 775,776.



Biphenyl (from benzene)

1. Function - Biphenyl can be manufactured in 85-90% yield by the vapor phase non-catalytic reaction of benzene. Benzene is placed in a stainless steel, tubular coil reactor and heated to 600-800°C at 101 kPa.
2. Input Materials  
Benzene
3. Operating Parameters  
Temperature - 600-800 (1112-1472°F)  
Pressure - 101 kPa (1 atm)  
Reaction Time - 0.4-1.5 sec
4. Utilities - Not given
5. Waste Streams - Some benzene, hydrogen, polyphenyls and benzene degradation products should be present in the waste streams.
6. EPA Source Classification Code - None
7. References  
U. S. Pat. 3,227,525 (January 4, 1966).  
Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 275.

Diphenyl Oxide

1. Function - Diphenyl oxide is produced in a continuous flow tubular reaction system. Aqueous NaOH, chlorobenzene, and recycled products (containing phenol and sodium phenoxide) are pumped through a Ni-lined heat exchanger which raises the temperature to 275-300°C. The temperature is raised to 400°C electrically and kept there for 10-30 min. during which time the reactants flow through the system. Two phases are obtained: 1) aqueous phenoxide, and 2) an oily layer which consists mainly of diphenyl oxide and unreacted chlorobenzene. This oily layer is distilled to produce the diphenyl oxide. The reaction must be carried out under sufficient pressure ( $\geq 26.2$  MPa) to prevent vaporization; otherwise, NaCl, NaOH, or phenoxide will deposit on the tube walls causing hot spots and excessive corrosion.

2. Input Materials

Chlorobenzene

Phenol

NaOH

3. Operating Parameters

Temperature: 1st Stage      275-300°C      (527-572°F)

2nd Stage      400°C      (752°F)

Pressure:  $\geq 26.2$  MPa (258.6 atm)

Reaction Time: 10-30 min.

4. Utilities

Not given

5. Waste Streams - Sodium hydroxide, sodium chloride, and sodium phenoxide should be present in the aqueous waste streams; chlorobenzene and phenol should also be emitted.

6. EPA Source Classification Code

None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 15 (1968) p. 154.

Chemical Technology, Barnes and Noble Books, New York, N.Y., 1972, p. 342.

SECTION II  
BUTYLENES

# BUTYLENES

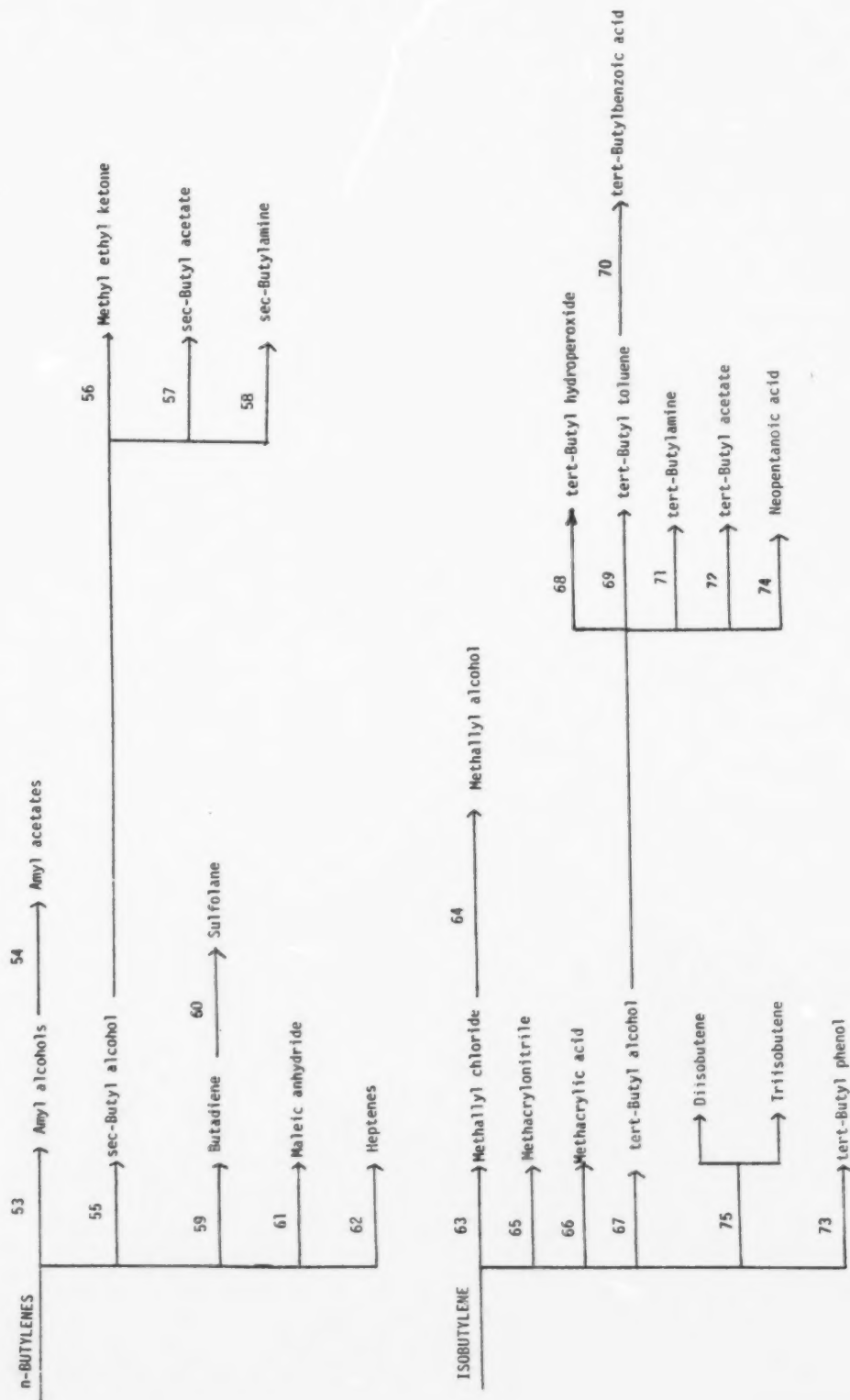


Figure 3. Butylenes Section Chemical Tree

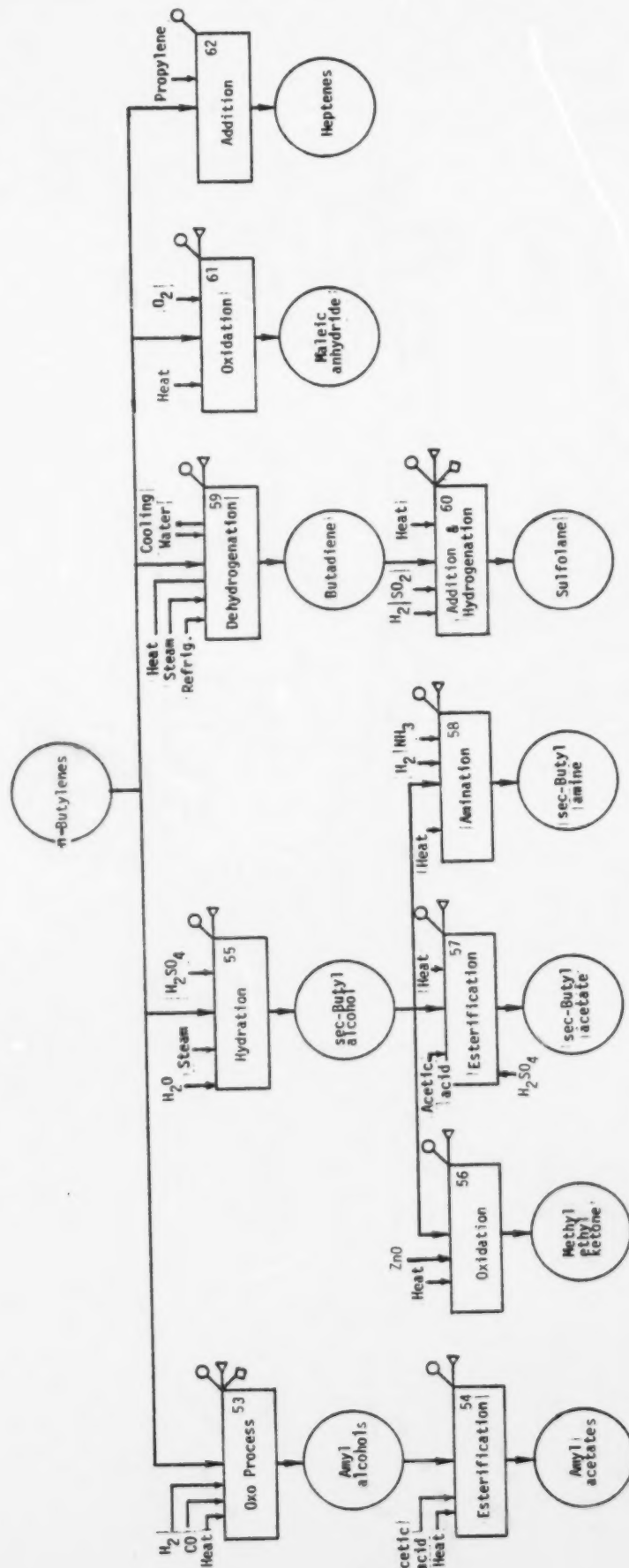


Figure 4. Butylenes Section Process Flow Sheet

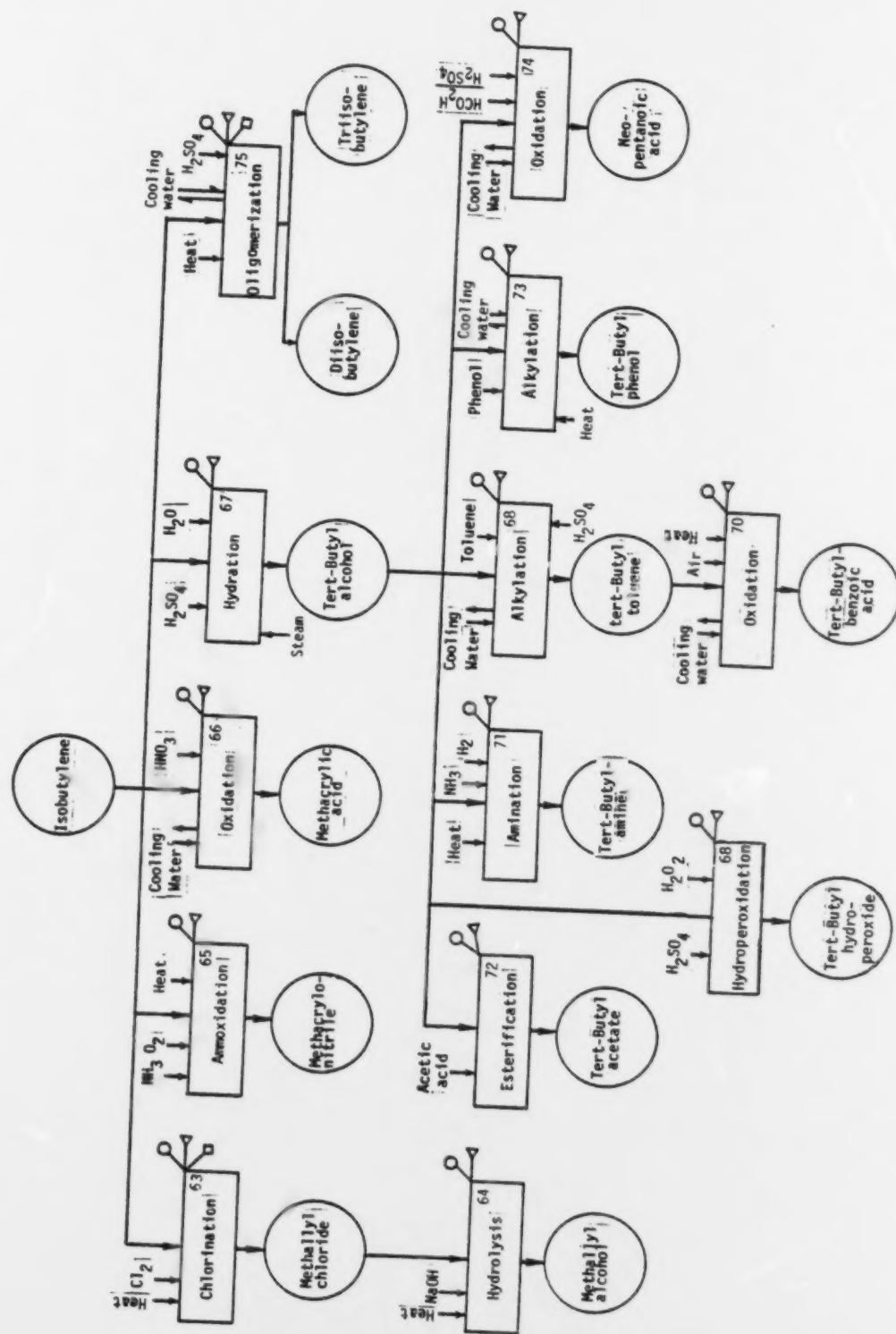
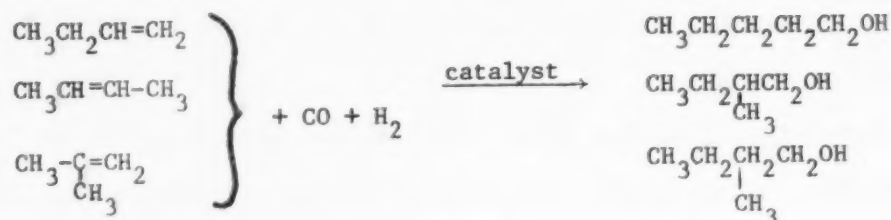


Figure 4. Butylenes Section Process Flow Sheet (Cont.)



Amyl Alcohols

1. Function - The manufacture of oxo amyl alcohols entails the reaction of butylenes with carbon monoxide and hydrogen at high pressure and temperature in the presence of a catalyst, usually a cobalt carbonyl compound. The reaction produces a mixture of primary C<sub>5</sub> alcohols which are fractionated into 3 commercial grades: primary amyl alcohol being approximately 60% 1-pentanol, 35% 2-methyl-1-butanol, and 5% 3-methyl-1-butanol; 1-pentanol being about 99% 1-pentanol; commercial 2-methyl-1-butanol consisting of 78% 2-methyl-1-butanol, 20% 3-methyl-1-butanol and 2% 1-pentanol.

2. Input Materials

Mixed butylenes - 1-Butene  
                           2-Butene  
                           Methylpropene

Synthesis gas - CO  
                           H<sub>2</sub>

3. Operating Parameters

Pressure - 20.65 MPa (200 atm)  
 Temperature - 125-145°C (257-293°F)

4. Utilities

Not given

5. Waste Streams - Catalyst recovery section (air, water). Air vent discharges some carbon monoxide, butylenes and alcohols. Some catalyst recovery systems have a water waste stream which could contain small quantities of alcohols.

Purification section (air). Various by-products are formed in the oxo process, mainly dimeric alcohols and acetals. In fractionation the heavy ends may be sent for incineration while some of the light ends may be flared to the atmosphere.

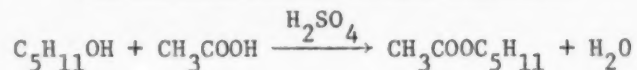
6. EPA Classification Code - None

7. References

Denney, R. G., "Oxo Alcohols," Report no. 21, Stanford Research Institute, Menlo Park, California, 1966.

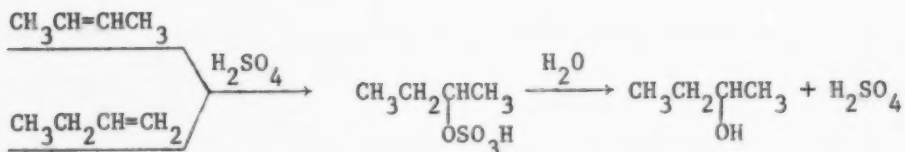
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 377,378.

Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4 (1972), p. 139.

Amyl Acetates (from amyl alcohols)

1. Function - Commercial amyl acetate, a mixture of isomers, is prepared by the esterification of mixed amyl alcohols with acetic acid. Small amounts of sulfuric acid are used to catalyze the reaction. The crude product is purified by rectification. The principal isomers are isoamyl, normal, and secondary amyl acetates.
2. Input Materials  
Amyl alcohols - 0.8 kg/kg product  
Acetic acid - .505 kg/kg product
3. Operating Parameters  
Temperature - 220-130°C (428-590°F)  
Pressure - 101 kPa (1 atm)  
Catalyst -  $\text{H}_2\text{SO}_4$
4. Utilities - Not given
5. Waste Streams - Air and wastewater emissions from separator and other purification equipment may contain acetic acid, amyl alcohol, amyl acetate, traces of sulfuric acid, and various reaction by-products.
6. EPA Source Classification Code - None
7. References

Goldstein, R. F., The Petroleum Chemicals Industry, 2nd Edition,  
John Wiley and Sons, New York, N.Y., 1958, p. 74,75.

sec-Butyl Alcohol

1. Function - In this process sec-butyl alcohol is produced by absorbing n-butenes in 70-85% sulfuric acid to form butyl hydrogen sulfate which is then hydrolyzed to sec-butyl alcohol and dilute sulfuric acid. The product is steam stripped from the dilute acid solution and purified by distillation.
2. Input Materials  
n-Butenes - 900 kg/Mg alcohol  
Sulfuric acid
3. Operating Parameters  
Sulfation: temperature - 15-30°C (55-78°F)  
                  pressure - 698.8 kPa (100 psig) (7.2 atm)  
Hydrolysis: temperature - 30-40°C (78-94°F)  
                  pressure - 100 kPa
4. Utilities - Not given
5. Waste Streams -  
Distillation column (water) - Waste stream would contain some butyl alcohol. If the process includes a caustic wash, there will be some sodium hydroxide and sodium sulfate in the wastewater.

Acid recovery section (water) - Sulfuric acid is wasted as tars build up.

6. EPA Source Classification Code - None

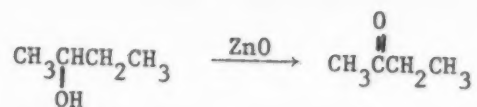
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Faith, W. L. et al., Industrial Chemicals, 2nd Edition, John Wiley and Sons, New York, N. Y., 1957.

Astle, M.J., The Chemistry of Petrochemicals, Reinhold Publishing Corporation, New York, 1956.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, Vol. 3 (1964).

Waddams, A.L., Chemicals From Petroleum, 3rd Ed., John Murray Ltd., London, 1973 , p. 159.

Methyl Ethyl Ketone

1. Function - Methyl ethyl ketone (2-butanone, or MEK) is made from sec-butanol by a process substantially the same as the acetone-from-isopropanol process. A catalyst of ZnO on pumice is used in a tubular reactor and the reactor temperature is maintained at 400-500°C.

Some MEK is obtained as byproduct from the oxidation of butane to acetic acid, some from the acetaldehyde process, and some from the acetaldehyde-to-acetic acid process.

2. Input Materials

sec-Butanol - 1175 kg/metric ton MEK

ZnO

3. Operating Parameters

Temperature - 400-550°C (752-1022°F)

Pressure - 200-300 kPa (15-30 psi) (1.97-2.96 atm)

Catalyst - ZnO

4. Utilities - Not given

5. Waste Streams - Scrubber (water): Wastewater stream would contain methyl ethyl ketone and reaction by-products.

6. EPA Source Classification Code - None

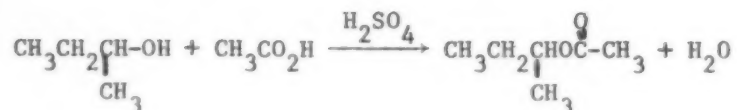
7. References

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., (1975) p. 539-542.

7. References (continued)

Sittig, M., Organic Chemical Process Encyclopedia 1969, 2nd Edition,  
Noyes Development Corporation, Park Ridge, New Jersey, (1969).



sec-Butyl Acetate

1. Function - The esterification of sec-butyl alcohol with acetic acid with concentrated sulfuric acid as a catalyst yields sec-butyl acetate. This reaction is reversible and so the water of reaction and the ester product must be continuously withdrawn to increase the conversion going to the ester. The overhead is usually a mixture of alcohol, ester, and water which is separated and the ester purified by rectification.
2. Input Materials - Basis - 1 Mg ester  
sec-Butyl alcohol: 713 kg  
Acetic Acid: 550 kg  
H<sub>2</sub>SO<sub>4</sub>: 1-4 kg
3. Operating Parameters  
Temperature: 89°C (192°F)  
Pressure: 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Separator  
(Water) - 1% ester  
3% alcohol  
96% H<sub>2</sub>O  
(Air) - ester and alcohol vapors from air vent; some H<sub>2</sub>SO<sub>4</sub>
6. EPA Source Classification Code - None

7. References

Faith, W. L., et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N.Y., 1965, p. 176-178.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1966), p. 372.

Groggins, P. H., Unit Operations in Organic Synthesis, 5th Edition, McGraw-Hill Book Company, New York, N.Y., 1958, p. 730.

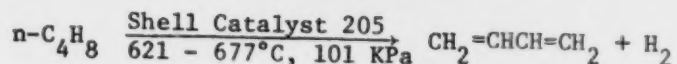
Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 173-176.

sec-Butyl Amine

1. Function - Sec-butyl amine is produced commercially by the catalytic addition of  $\text{NH}_3$  to the corresponding alcohol, with separation of the mono-, di- and tri-substituted butyl amines.
2. Input Materials - Basis - 1 Mg mixed product  
Sec-butanol: 1.5 Mg (7.5 mole %)  
 $\text{NH}_3$ : 425 kg (45 mole %)  
 $\text{H}_2$ : (43 mole %)
3. Operating Parameters  
Temperature: 350°C (662°F)  
Pressure: 1.48 MPa (14.6 atm)  
Flow rate: 1000/hr space velocity  
Catalyst: Nickel  
These conditions yield: 50 mole percent monoamine  
20 mole percent diamine  
30 mole percent triamine
4. Utilities - Not given
5. Waste Stream -  $\text{CO}_2$  and formaldehyde by-products; unreacted alcohols,  $\text{H}_2$ , and  $\text{NH}_3$  in vented gas streams.
6. EPA Source Classification Code - None
7. References  
Faith, W. L. et al., Industrial Chemicals, John Wiley and Sons, New York, N. Y., 1950, p. 47, 48.

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 127.

U. S. Patent 2,182,807 (December 12, 1939).

Butadiene (catalytic dehydrogenation of n-butenes)

1. Function - n-Butenes which have been treated for isobutylenes and butanes removal are the exclusive feed for 15-20% of the butadiene manufactured in the U.S. Two commercial processes compete: one of which is based on the Dow Type B catalyst, the other on Shell Catalyst 205.

Shell Catalyst 205 (ferric oxide, chromium oxide, and potassium oxide) effects dehydrogenation to butadiene at temperatures of 621-677°C and atmospheric pressure. The preheated butene feedstock is mixed with superheated steam in a mole ratio of 1:8 and passed over the 81-91 cm. deep catalyst bed at a space velocity of 500 volumes of butenes at standard condition per hour, per volume, of catalyst space. Selectivity to butadiene is 73-75% with 26-28% conversion of n-butene per pass.

The more recently developed Dow Type B catalyst (calcium nickel phosphate stabilized with 2% chromium oxide) effects dehydrogenation at slightly lower temperatures (593-677°C) and higher pressures (170-255 kPa) than Shell Catalyst 205.

Selectivity to butadiene (90%) and butene conversion per pass (35-45%) are significantly higher with this catalyst, but larger quantities of diluent steam (1:20) and more frequent catalyst regeneration are required. Whereas Shell Catalyst 205 is regenerated only

once a day for one hour, the Dow Type B Catalyst must be regenerated in fifteen minute cycles.

This catalyst also has a greater tendency to produce ketones and acetylenic by-products than Shell Catalyst 205. Although marketable quantities of acetone and methyl ethyl ketone may be obtained, their separation requires more extensive purification equipment.

The resulting butane/butene/butadiene mixture is separated by extractive distillation with aqueous furfural or acetonitrile. Butenes and butanes are collected overhead and recycled, while butadiene and residual acetylenics remain in the solvent bottoms. Since furfural cannot be used to separate butadiene from the 2-butenes, it is frequently advantageous to precede the extractive distillation with a feed splitter. This column takes most of the butanes and 2-butenes as bottoms, and passes the 1-butene/butadiene overhead into the furfural unit. Alternately, a final butadiene fractionator may be used on the 2-butene/butadiene concentrate stripped from the furfural solvent.

If acetonitrile is used as the extraction solvent, butanes and butenes separate almost quantitatively from butadiene and feed splitting is not required. However, a final water wash is necessary to remove the last traces of solvent from both the raffinate and product streams. Washing is not required to recover furfural due to the high boiling point of the solvent.

## 2. Input Materials

n-Butenes - (80-95%)

Shell Catalyst 205 - 1.38-1.42 kg/kg product

Dow Type B Catalyst - 1.14-1.18 kg/kg product

Hydrogen - (acetylenics removal)

Furfural or acetonitrile

3. Operating Parameters

Shell Catalyst 205 - temperature: 621-677°C (1150-1251°F)  
pressure: 101 kPa (1 atm)

Dow Type Catalyst - temperature: 593-677°C (1099-1251°F)  
pressure: 170-255 kPa (1.68-2.52 atm)

4. Utilities - Basis: 1.43 kg/sec capacity (100 M lb/yr)

Water: cooling - 272 m<sup>3</sup>/sec (43,130 gpm)  
process and makeup - 118.0 dm<sup>3</sup>/sec (1870 gpm)

Power: 10.9 MW (14,600 hp)

Refrigeration: chilled water - 2.48 Gg (2735 tons)  
ammonia - 1.65 Gg (1820 tons)

Steam (at 4.24 MPa (41.8 atm), 399°C (750°F): 302 kg/sec (2400 lb/hr)

Natural gas: 2.41 m<sup>3</sup>/sec (306,000 cfh)

5. Waste Streams - Waste flows from butadiene production facilities were 417 m/Gg (100 gal/ton) of product with waste composition as follows (taken from one source only):

pH: 8-9

TOC: 100 to 200 g/m<sup>3</sup>

Filtered COD: 250 to 375 g/m<sup>3</sup>

Suspended solids: 200 to 500 g/m<sup>3</sup>

Total solids: 3 to 4 kg/m<sup>3</sup>

The principal pollutant sources should be the quench waters containing tars, oils, and soluble hydrocarbons and the solvent extract and wash waters (if acetonitrile is used) containing acetonitrile and C<sub>4</sub> hydrocarbons. Some air emissions of furfural or acetonitrile may also occur.



6. EPA Source Classification Code - None

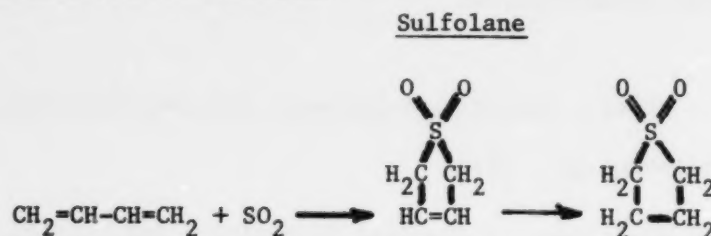
7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 794-799.

Sittig, M., Organic Chemical Processes Encyclopedia - 1969, 2nd Edition Noyes Development Corp., Park Ridge, N.J., 1969, p. 118.

U. S. Pat. 3,200,166 (August 10, 1965).



1. Function - Sulfolane is produced by the cyclic addition of sulfur dioxide to butadiene to form sulfolene. The reaction is carried out in a Cr-steel tube (1300 x 100 mm) filled with catalyst. The crude product is treated with a chloride of lime suspension (to remove any mercaptans found) and then distilled. The sulfolene is then hydrogenated to sulfolane.

Steps must be taken to keep peroxides from entering the reaction with the reactants because undesirable polymeric by-products will result.

2. Input Materials

|          |                                       |         |                 |       |       |
|----------|---------------------------------------|---------|-----------------|-------|-------|
| Catalyst | 20% Cr <sub>2</sub> O <sub>3</sub>    | 3.70 kg | Butadiene       | 467   | kg/Mg |
|          | 0.58% K <sub>2</sub> O                |         | SO <sub>2</sub> | 553.4 | kg/Mg |
|          | 79.42% Al <sub>2</sub> O <sub>3</sub> |         | H <sub>2</sub>  | 17.3  | kg/Mg |

3. Operating Parameters

Temperature 500°C (932°F)

4. Utilities

Steam - quantities not given

5. Waste Streams - Possible waste streams should contain some SO<sub>2</sub>, nickel, catalyst, and some polymeric byproducts.

6. EPA Source Classification Code

None

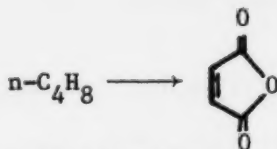
7. References

Drake, L. R., et. al., J. Amer. Chem. Soc., 68, p. 2521 (1946).

U.S. Patent 2,420,834 (May 20, 1947).

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed.

Interscience Publishers, New York, N.Y., Vol. 19 (1969) p. 250.

Maleic Anhydride

1. Function - Butenes are oxidized to maleic anhydride at a temperature of 350°C and a pressure of 276-450 kPa (25-50 psig). A catalyst is used for this oxidation which consists of the oxides of molybdenum, vanadium, and phosphorous (in a ratio of 9:3:1), supported on silica gel. The maleic anhydride is solvent extracted from the reaction gases and purified by vacuum distillation or sublimation.
2. Input Materials  
Butenes  
Air  
Catalyst (oxides of Mo, V, P on silica gel)
3. Operating Parameters  
Temperature: 350°C  
Pressure: 276-450 kPa (2.7 - 4.4 atm)  
Contact time: 1.5 sec.
4. Utilities  
Cooling water - quantities not given  
Steam - quantities not given
5. Waste Streams - Recovery section - air emissions containing butenes, carbon oxides and traces of maleic acid  
Purification section - waste water stream from bottoms containing maleic anhydride and high boilers. Another waste water stream from overhead containing maleic acid.

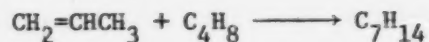
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 828,  
829.

Morse, P. L., Maleic Anhydride, Report No. 46, Stanford Research  
Institute, Menlo Park, California, 1969.

U.S. Patents 3,156-705 - 3,156,707 (1964).

Heptenes

1. Function - Heptenes are a cut fractionated from the gasoline mixture that is produced by polymerizing  $\text{C}_3$ - $\text{C}_4$  refinery gases.

In general, the yield of heptenes is about 25% based on propylene and 33% based on n-butene and isobutene. However, these figures vary considerably, depending on the reaction conditions and the feed composition.

2. Input Materials

$\text{C}_3$  Refinery gas

Propylene: 1.7 kg/kg heptene

$\text{C}_4$  Refinery Gas

Butylenes: 1.71 kg/kg heptene

3. Operating Parameters

Temperature: 200-240°C (392-464°F)

Pressure: 1.52-2.53 MPa (15-25 atm)

Catalyst:  $\text{H}_3\text{PO}_4$

4. Utilities

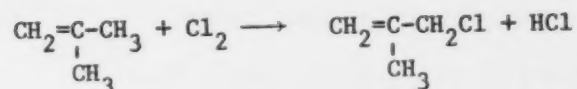
Not given

5. Waste Streams - Since all the fractions of the gasoline mixture product are utilized, there are no wastes from this process. However, any number of olefins may be released to the atmosphere in small quantities by process leaks.
6. EPA Source Classification Code - None
7. References

Goldstein, R. F., The Petroleum Chemicals Industry, 2nd Edition, John Wiley and Sons, New York, N.Y., 1958 , p. 125.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Murray Ltd., London, England, 1973, p. 137, 144.



Methallyl Chloride

1. Function - Isobutylene and chlorine are mixed in a ratio of 2:1 at 70-80°C to yield methallyl chloride. The main mechanism of this reaction is an allylic substitution.

The crude product is recovered by distillation with the overhead being approximately 95% methallyl chloride.

2. Input Materials

Isobutylene }  
Chlorine } 2/1 molar ratio

3. Operating Parameters

Temperature: 70-80°C (158-176°F)

4. Utilities

Steam: quantity not given

5. Waste Streams - Distillation column: heavy ends may be incinerated  
some Cl<sub>2</sub> and HCl vapors may be present in the waste streams.

6. EPA Source Classification Code

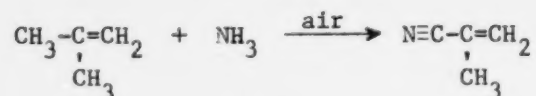
None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol 3 (1964), p. 840, 841.  
  
Faith, Clark, & Keyes, Industrial Chemicals, 2nd Edition, J. Wiley  
& Sons, Inc., New York, 1950.

Methallyl Alcohol

1. Function - Methallyl alcohol is produced from methallyl chloride by hydrolysis with caustic solution.
2. Input Materials  
Methallyl chloride  
NaOH (10%)
3. Operating Parameters  
Temperature: 145-155°C (293-311°F)  
Pressure: 1.5 MPa (19.8 atm)  
Reaction Time:  $\leq$  15 minutes
4. Utilities - Not given.
5. Waste Streams - Wastewater streams would have some NaOH, NaCl, alcohol, and chloride.
6. EPA Source Classification Code - None.
7. References  
Goldstein, R. F., The Petroleum Chemicals Industry, 2nd Edition, John Wiley and Sons, New York, N. Y., 1958, p. 171.  
  
Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Corp., New York, N. Y., 1956, p. 69.

Methacrylonitrile

1. Function - Methacrylonitrile is produced by the aminoxidation of isobutylene. Isobutylene, ammonia, and air are fed to a fluid-bed catalytic reactor operating at 800-900°C. The reactor effluent is scrubbed and the product recovered by distillation.

2. Input Material

Isobutylene - 1 kg/kg product

Ammonia - 0.5 kg/kg product

Air - 20 kg/kg product

3. Operating Parameters

Temperature: 800-900°C (1472-1652°F)

Catalyst: oxide of Co, Mn, or Mo

4. Utilities

Cooling water: 470 kg/kg product

Steam: 6.5 kg/kg product

Refrigeration: capacity not given

Process water: 100 kg/Mg product

Electricity: capacity not given

5. Waste Streams

Reaction section - absorber off-gas to flare (air)

Methacrylonitrile - 5 kg/Mg product

Carbon monoxide - 200 kg/Mg product

Isobutylene - 100 kg/Mg product

Ammonia - trace

Purification section - off-gas from drying column to flare (air)

Hydrogen cyanide - 1 kg/Mg product

Reaction section - neutralizer (water)

Wastewater contains ammonium sulfate

Purification section - stripper (water)

Wastewater may contain by-products such as acetonitrile

6. EPA Source Classification Code - None

7. References

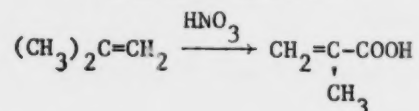
Kent, J. A., Editor, Riegel's Handbook of Industrial Chemistry,

Van Nostrand Reinhold Company, New York, N. Y., 1974, p. 810.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,

Interscience Publishers, New York, N. Y., Vol. 13 (1967), p. 333,

342.

Methacrylic Acid

1. Function - Methacrylic acid is produced by the thermally activated reaction of isobutylene with nitric acid or mixtures of this acid with  $\text{N}_2\text{O}_4$ . The initial oxidation proceeds at low temperatures ( $0-5^\circ \text{C}$ ), and in several intermediate stages the oxidation products are converted to  $\alpha$ -hydroxyisobutyric acid, which is then dehydrated to methacrylic acid.

A plant was built in Pensacola, Florida, by Escambia Chemical Corporation to use this process. There were some economic problems with the process and its present status is unknown.

2. Input Materials

Isobutylene

Nitric acid

3. Operating Parameters

Initial oxidation stage: temperature -  $0-5^\circ \text{C}$  ( $32-41^\circ \text{F}$ )

Subsequent oxidation stages: temperature - higher but unknown

4. Utilities - Chilling water - quantities not given

5. Waste streams - No data available. It is presumed that some isobutylene and oxidation products would be released to the atmosphere through leaks and vents.

6. EPA Source Classification Code - None

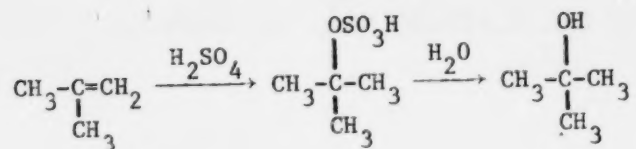
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 842.

Anon., Chemical Week, 90(26), 17 (1962).

Fr. Pat. 1,335,166 (July 8, 1963).

U.S. Pat. 2,847,453 (Aug. 12, 1958).

tert-Butyl Alcohol

1. Function - Isobutylene is absorbed in sulfuric acid to form t-butyl hydrogen sulfate which is subsequently hydrolyzed with water to t-butyl alcohol and dilute sulfuric acid. The product is steam stripped from the acid solution and purified by distillation.

The process is similar to that for sec-butyl alcohol except for the sulfuric acid being less concentrated (60-65% vs 75-80%) to minimize polymerization reactions.

2. Input Materials

Isobutylene - 850 kg/Mg alcohol

Sulfuric acid - recycled

3. Operating Parameters

Sulfation: Temperature - 30-45°C (86-113°F)

Pressure - not given

Hydration: Temperature 30-40°C (86-104°F)

Pressure - not given

4. Utilities - Not given



5. Waste Streams -

Distillation column (water) - Some t-butyl alcohol will be present in the waste water. If caustic washing is included the waste water stream will contain some sodium hydroxide and sodium sulfate.

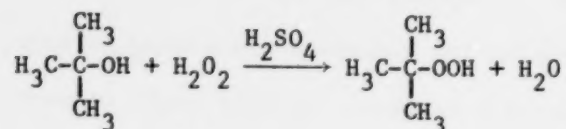
Acid recovery section (water) - As tars build up some sulfuric acid is wasted in the effluent stream.

6. EPA Source Classification Code - none

7. References

Astle, M.J., The Chemistry of Petrochemicals, Reinhold Publishing Corporation, New York, 1956.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, Vol. 3 (1964), p. 827.

tert-Butyl Hydroperoxide

1. Function - The formation of t-butyl hydroperoxide can be achieved by three different methods. First, the alkylation of hydrogen peroxide by alkyl sulfates, chlorides or alcohols in the presence of sulfuric acid. Second, the oxidation of an appropriate hydrocarbon, in this case isobutane, in the presence of a chain initiator (HBr), and third, the oxidation of an appropriate Grignard reagent with oxygen saturated ether. The method of choice is the alkylation of hydrogen peroxide with t-butyl alcohol in the presence of sulfuric acid.

The t-butyl alcohol, 30-50% hydrogen peroxide, in equimolar quantities, and sulfuric acid are combined in a water-immiscible solvent (chloroform or methylene chloride) having a boiling point lower than that of t-butyl hydroperoxide. The reaction is carried out at 60°C with very rapid stirring, necessary because of the dual phase system, for a short period of time (1/2 - 1 hour). The reaction mixture is rapidly cooled and the organic solvent evaporated under reduced pressure. The yields are 70-80% of a 97% pure product. The t-butyl hydroperoxide may be purified by vacuum distillation provided the pressure is maintained at 100 mm or less at which point the boiling point (53°C) is below the decomposition temperature (73°C) of the hydroperoxide.

2. Input Materials

t-Butyl alcohol

30% Hydrogen peroxide

70% Sulfuric acid

Methylene chloride or chloroform

3. Operating Parameters

Temperature - 60°C (140°F)

Pressure - 100 kPa (1 atm)

Catalyst - sulfuric acid

4. Utilities - Not given

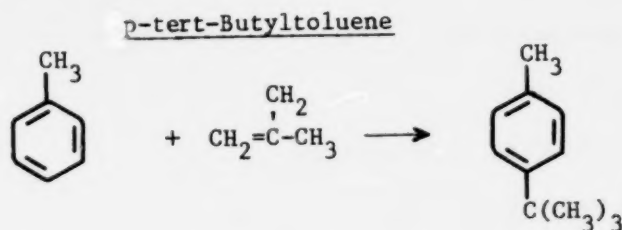
5. Waste Streams - Vent streams from the reaction vessel and purification system contain organic solvent vapors. Wash water, sulfuric acid, t-butyl alcohol and some t-butyl hydroperoxide.

6. EPA Source Classification Code - None

7. References

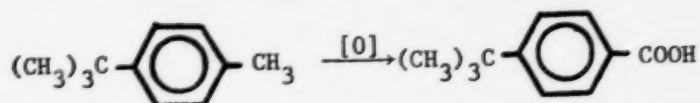
"Encyclopedia of Polymer Science and Technology, Vol. 9, Interscience Publishers, New York, New York, 1968, p. 815.

U. S. Patent 2,573,947 (1951 Shell Development Co.).



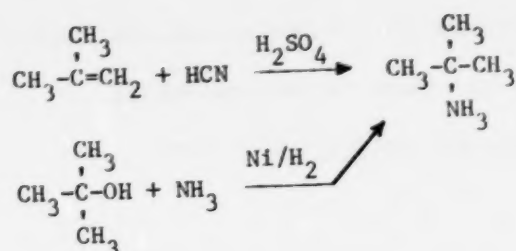
1. Function - Toluene is alkylated with isobutylene or tert-butyl alcohol in the presence of sulfuric acid. The alcohol dehydrates readily in the acidic conditions of this process. The alkylation proceeds very cleanly if temperatures are controlled to no more than 75 to 80°C. The product is washed in a caustic scrub to remove the last traces of acid catalyst.
2. Input Materials  
Isobutylene or tert-butyl alcohol  
Toluene  
Sulfuric acid
3. Operating Parameters  
Temperatures: 75 to 80°C (167-176°F)  
Pressure: 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Wastewater stream from caustic scrubbing would contain spent caustic and traces of product.
6. EPA Source Classification Code - None
7. References  
Schlatur, M. J. and Clark, R. D., J. Amer. Chem. Soc., Vol. 75 (1953), p. 361-369.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N. Y., Vol. 3 (1964), p. 873.

p-tert-Butylbenzoic Acid

1. Function - The stable character of the tert-butyl side chain on tert-butyltoluene toward oxidation leads to the production of tert-butylbenzoic acid by air oxidation. In this process, a cobalt catalyst is used and a temperature of 110-180°C with a pressure of about 450-625 kPa (4.4-6.2 atm). Water is removed as soon as it is formed. Generally, the tert-butylbenzoic acid is isolated by crystallization or by extraction and crystallization.
2. Input Materials  
tert-Butyltoluene: 850 kg/Mg acid  
Air: approximately 2 Mg/Mg acid
3. Operating Parameters  
Temperature: 110-180°C (230-356°F)  
Pressure: 450-625 kPa (4.4-6.2 atm)  
Catalyst: a cobalt compound
4. Utilities  
Steam - quantities not given
5. Waste Streams - The water of reaction removed from the process would probably carry small quantities of both product and reactant.
6. EPA Source Classification Code - None
7. References

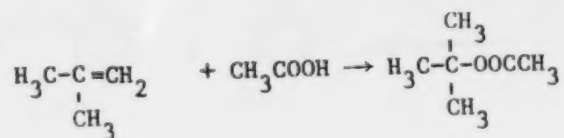
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 436.

tert-Butylamine

1. Function - Two routes are used to produce tert-butylamine: (1) isobutylene or tert-butyl alcohol is reacted with HCN in the presence of sulfuric acid at a temperature of 25°C; the alcohol dehydrates readily in acid and reacts the same as isobutylene with the HCN; (2) tert-butyl alcohol is reacted with ammonia at 190°C in the presence of a nickel catalyst and hydrogen.
2. Input Materials
  - (1) Isobutylene or tert-butyl alcohol
    - Hydrogen cyanide
    - Sulfuric acid
  - (2) tert-Butyl alcohol
    - Ammonia
    - Hydrogen
3. Operating Parameters
  - (1) Temperature: must be carefully controlled to around 25°C (77°F) to prevent polymerization
  - (2) Temperature: 190°C (374°F)
4. Utilities - Not given

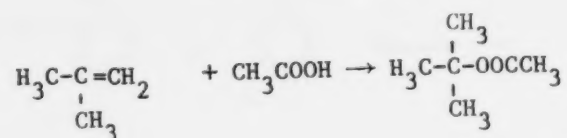


5. Waste Streams - No specific information available but purification would give wastewater streams containing spent catalyst and products in small amounts. Vents in process 2 could allow some ammonia and hydrogen to escape to the atmosphere.
6. EPA Source Classification Code - None
7. References  
Faith, W. L. et al., Industrial Chemicals, 2nd Edition, John Wiley and Sons, New York, N. Y., 1957, p. 53, 54.

tert-Butyl Acetate

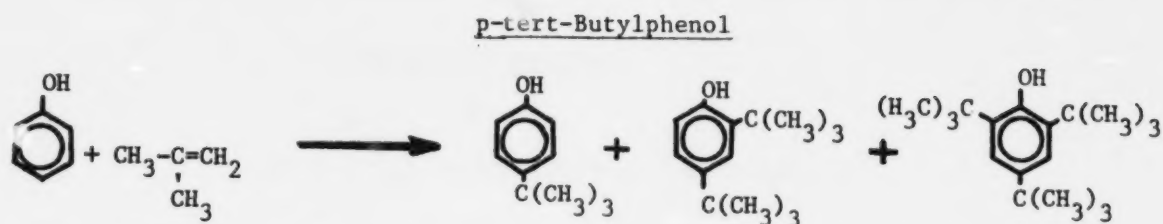
1. Function - Reacting isobutylene with glacial acetic acid in the liquid phase over a silica catalyst impregnated with  $\text{V}_2\text{O}_5$  and  $\text{K}_2\text{SO}_4$  at  $93.3^\circ\text{C}$  ( $200^\circ\text{F}$ ) and 1.72 MPa (17.0 atm) yields tert-butyl acetate. Exxon Corporation is the only company which reported production of the acetate to the U.S. Tariff Commission.
2. Input Materials  
Glacial acetic acid
3. Operating Parameters  
Temperature  $93.3^\circ\text{C}$  ( $200^\circ\text{F}$ )  
Pressure 1.72 MPa (17.0 atm)
4. Utilities  
Not given
5. Waste Streams - Purification would give a wastewater stream which could contain small amounts of acid, acetate, alcohol, and catalysts.
6. EPA Source Classification Code  
None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 342.

tert-Butyl Acetate

1. Function - Reacting isobutylene with glacial acetic acid in the liquid phase over a silica catalyst impregnated with  $\text{V}_2\text{O}_5$  and  $\text{K}_2\text{SO}_4$  at  $93.3^\circ\text{C}$  ( $200^\circ\text{F}$ ) and 1.72 MPa (17.0 atm) yields tert-butyl acetate. Exxon Corporation is the only company which reported production of the acetate to the U.S. Tariff Commission.
2. Input Materials  
Glacial acetic acid
3. Operating Parameters  
Temperature  $93.3^\circ\text{C}$  ( $200^\circ\text{F}$ )  
Pressure 1.72 MPa (17.0 atm)
4. Utilities  
Not given
5. Waste Streams - Purification would give a wastewater stream which could contain small amounts of acid, acetate, alcohol, and catalysts.
6. EPA Source Classification Code  
None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 342.



1. Function - Isobutylene reacts quite readily with phenol in the presence of any of a wide range of acidic and Friedel-Crafts catalysts to give, successively, the mono-, di-, and tri-tert-butylphenols.

Under acidic condition, tert-butyl alcohol dehydrates readily and yields the same alkylated phenols as the isobutylene. High temperatures favor dealkylation and trisubstituted tert-butylphenols.

2. Input Materials

Isobutylene or tert-butyl alcohol

Phenol

Acidic (50% H<sub>2</sub>SO<sub>4</sub>) or Friedel-Crafts catalysts

3. Operating Parameters

Temperature: controlled to 70°C (158°F), then taken to 150°C (302°F)

Pressure: atmospheric

Reaction Time: 1 hr

4. Utilities

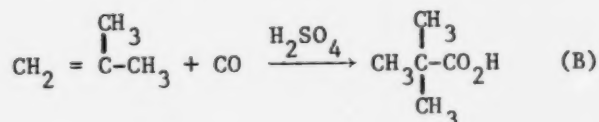
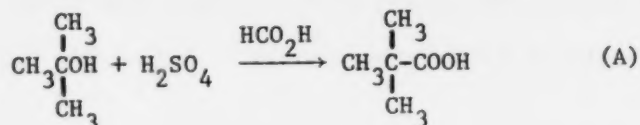
Not given

5. Waste Streams - No specific information available but it is probable that purification procedures would give wastewater streams containing traces of mixed isomeric butylphenols, isobutylene polymers, and H<sub>2</sub>SO<sub>4</sub> or Friedel-Crafts catalysts.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 1 (1963) p. 904.

Neopentanoic Acid (pivalic acid)

1. Function - Neopentanoic acid is made by two different processes. In one process (A) tert-butyl alcohol is reacted with sulfuric acid and formic acid at a temperature of 20-25°C. The product is purified by distillation.

The other process (B) involves the carboxylation of isobutylene with carbon monoxide in aqueous sulfuric acid. The isobutylene and acid catalyst are pumped to a pressurized reaction vessel where a CO rich gas is bubbled through the mixture to form a tertiary carbonium ion. After degassing, the complex is hydrolyzed with water to spring the acid catalyst for recycle. The crude acid is treated to remove the last traces of catalyst and then purified by distillation.

2. Input Materials

(A) tert-Butyl alcohol

Formic acid

Sulfuric acid

(B) Isobutylene

Carbon monoxide

Dilute  $\text{H}_2\text{SO}_4$

### 3. Operating Parameters

(A) Temperature: 20-25°C (68-77°F)  
Pressure: Not given

(B) Temperature: reaction - 20-60°C (68-140°F)  
distillation - 163-165°C (325-329°F)  
Pressure: reaction - 3.6 MPa (35.5 atm)  
distillation - 101 kPa (1 atm)  
Reaction time: 5-180 minutes

### 4. Utilities

Steam - Not given

Electrical power - Not given

### 5. Waste Streams

(A) Distillation bottom ends could give a wastewater stream containing small quantities of product and catalyst.

(B) Reactor off-gas will contain CO and isobutylene vapors. Water from springing of catalyst could give rise to a wastewater stream carrying some acid catalyst and crude product.

### 6. EPA Source Classification Code - None

### 7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 853,854.

Sittig, M., Chemicals From C<sub>4</sub> Hydrocarbons, Noyes Development Corp., Park Ridge, N.J., 1966, p. 88,89.



Di- And Tri-Isobutenes

1. Function - The isobutene in a  $C_4$  stream (free of butadiene) is absorbed in 50-65% sulfuric acid at 10-20°C and then heated to 80-100°C to coproduce diisobutylene and triisobutylene in the ratio of 80% to 20%. The oligomers separate as an upper layer which is separated, washed, and purified by distillation.

2. Input Materials

Isobutene

$H_2SO_4$  (recycled)

3. Operating Parameters

Temperature: extraction - 10-20°C (50-68°F)  
polymerization - 100°C (212°F)  
time - 0.5 hour

4. Utilities - Not given

5. Waste Streams - Caustic washes (water) - Waste stream contains sodium hydroxide, sodium sulfate, and organic by-products such as butyl alcohol.

Distillation column produces heavy ends.

6. EPA Source Classification Code - None

7. References

McKetta, J. J., Editor, Advances in Petroleum Chemistry and Refining, Interscience Publishers, New York, N. Y., Vol. 7 (1963), p. 285-321.

Goldstein, R. F., The Petroleum Industry Today, 2nd Edition, John Wiley and Sons, New York, N. Y., 1958, p. 125.

SECTION III

SOURCES OF CRESYLIC ACIDS

# SOURCES OF CRESYLIC ACIDS

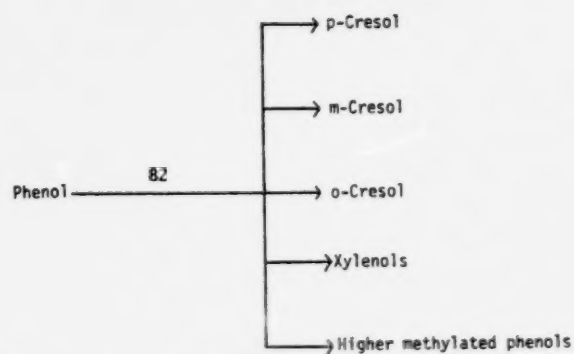
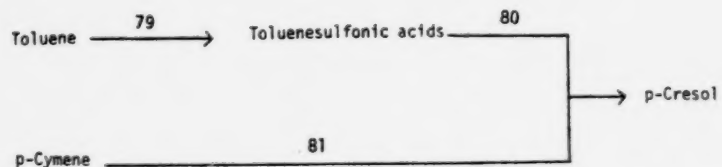
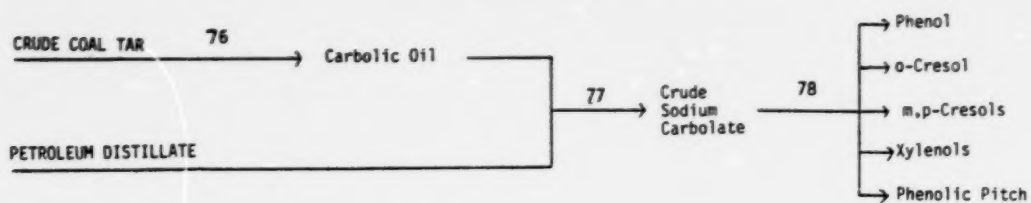


Figure 5. Sources of Cresylic Acids Chemical Tree

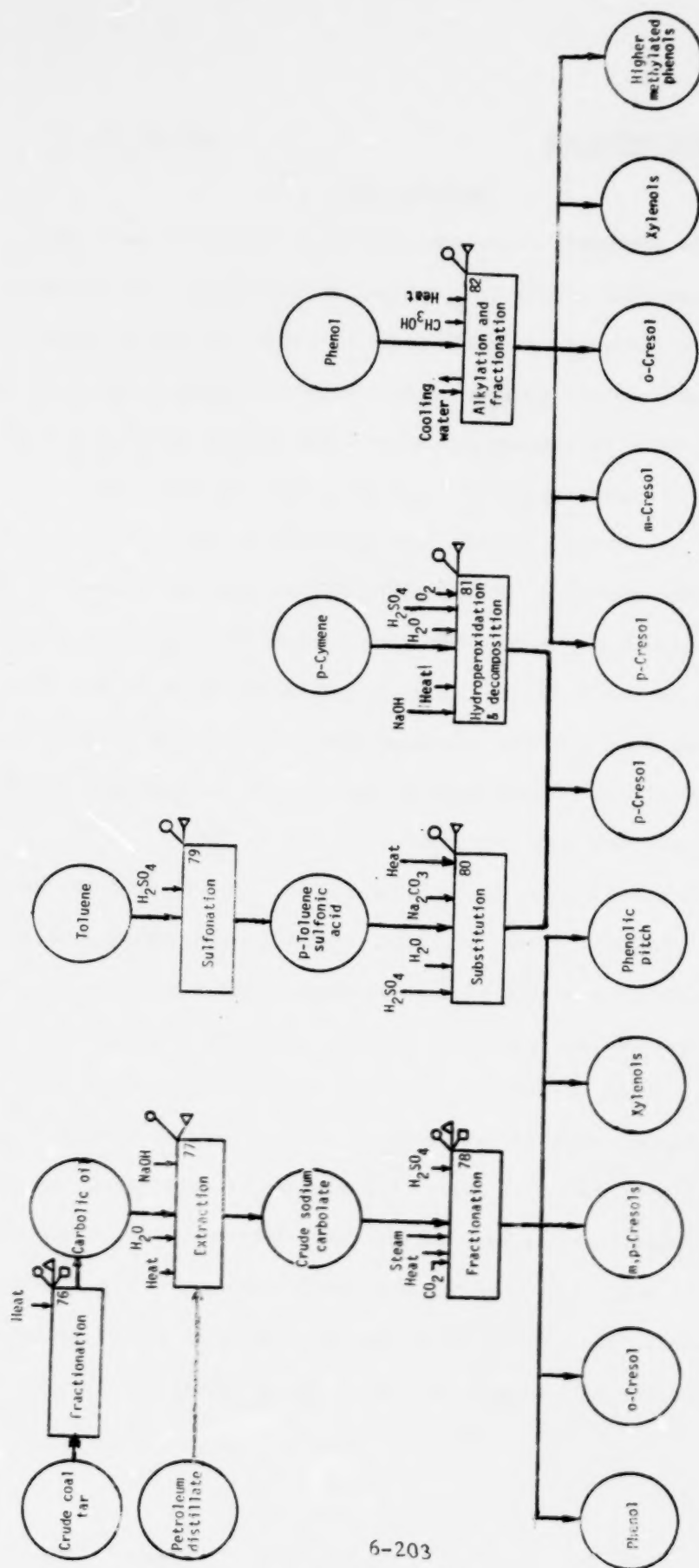


Figure 6. Sources of Cresylic Acids Process Flow Sheet

Carbolic Oil

1. Function - As produced, crude coal tar is of value only as a fuel. Today, at least 85% of the tar produced is distilled. The two main objectives in the primary distillation of crude tar are to obtain a pitch or refined-tar residue of the desired softening point and to concentrate those components which are subsequently to be recovered. In the case of continuous vertical-retort tar, the main aim is to concentrate the phenol, cresols, and xylenols in the carbolic oil fraction. The amount of "phenolic bodies" in coal tar depends on the carbonization process used. Coke-oven by-product tars contain between 1 and 7% of "phenolic bodies", the average being close to 3%. Gas-works tars derived from the carbonization of bituminous coal in continuous vertical retorts have an average tar acid content of 15% and low-temperature tars may contain as much as 25%.

Primary distillation of coal tar in the U. S. is done in "Recycle Continuous Stills". Crude tar, after screening and doping with alkali, is pumped through a series of heat exchangers and a waste-heat coil and then injected into the lower section of a dual flash chamber where it meets hot pitch overflowing from the upper section. The water and light-oil vapors released in the lower section pass up through a liquid seal into the upper part. The mixture of dehydrated tar and pitch is pumped from the base of the distillation column, through the furnace coil and, at a temperature of 360°C enters the upper chamber of the distillation column, where the oil vapors flash off assisted by the injection of superheated steam. These vapors and the vapors

from the lower section issue from the top of the distillation column into the base of the side-stream fractionating column. The pitch, which accumulates at the base of the upper section of the distillation column, is partly withdrawn as product and partly allowed to overflow into the lower section where it mixes with the crude tar before recycle through the furnace coils.

2. Input Materials

Crude coal tar

Steam

Alkali

3. Operating Parameters

Temperature - 360°C (680°F)

Pressure - not given

4. Utilities

Steam - quantities not given

5. Waste Streams - Small quantities of hydrocarbons would be expected to escape to the air from distillation columns.

|                  |                                          |           |
|------------------|------------------------------------------|-----------|
| Waste Flow       | 3.38 l/kg (405.3 gal/10 <sup>3</sup> lb) | 3.38 l/kg |
| COD              | 2,570 mg/lg                              |           |
|                  | 8.68 g/kg (1b/10 <sup>3</sup> lb)        |           |
| BOD <sub>5</sub> | 833 mg/l                                 |           |
|                  | 2.81 g/kg (1b/10 <sup>3</sup> lb)        |           |
| TOC              | 3,010 mg/l                               |           |
|                  | 10.16 g/kg (1b/10 <sup>3</sup> lb)       |           |

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 434.

Ibid, Vol. 19 (1969), p. 653.

Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corp., Park Ridge, N. J., 1974, p. 108-113.



Crude Sodium Carbolate

1. Function - Since only phenol, the cresols, and the lower-boiling xylenols are of commercial value, only those fractions obtained on the primary distillation of crude tar which distill between 185° and 240°C are treated for tar acid extraction. These oils (carbolic oil) are contacted with a slight excess of 8-10% caustic soda solution at the minimum temperature which will prevent crystallization of the naphthalene which is also usually a major component. Extraction may be carried out in stirred vessels, in packed or unpacked towers, in mixer-settler units, or simply by mixing the two streams by a gear pump.

The other major source of cresols in the U. S. is from petroleum. The petroleum-based cresols are obtained from spent caustic liquor used to wash petroleum distillates.

2. Input Materials

Carbolic oil

Petroleum distillates

NaOH

H<sub>2</sub>O

3. Operating Parameters

Temperature - not given

Pressure - atmospheric

4. Utilities - not given

5. Waste Streams - Caustic soda may be released in wastewater streams; small quantities of non-acidic hydrocarbons released to the air or wastewater streams.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 434.

Phenol, o-Cresol, m,p-Cresol, Xylenols and Phenolic Pitch

1. Function - Crude sodium carbolate is treated with live steam, sometimes after extraction with a phenol and base-free coal-tar naphtha or light creosote oil. The purified carbolate is then contacted counter-currently with a gas containing  $\text{CO}_2$  in packed towers. The springing medium may be flue gas containing 10-14%  $\text{CO}_2$  or a richer gas containing 30-35%  $\text{CO}_2$ . Conditions in the springing towers are generally adjusted so that the aqueous phase leaving this stage contains 2-3% of the available alkali as bicarbonate. After springing, the two layers are separated by decantation and the tar acid layer, which contains about 20% water, is retreated with the  $\text{CO}_2$  - containing gas to convert any residual carbonate to bicarbonate. Alternatively, the crude wet tar acids may be partially dehydrated by treating with concentrated sulfuric acid. The partly dried tar acids are first distilled to yield water containing some phenol (this fraction is recycled to the extraction stage), a main fraction of "once-run tar acids", and a residue of phenolic pitch. The main fraction is fractionated in two or three continuous columns to yield phenol, o-cresol, m,p-cresol mixture and xylenols.

The same procedure may be used in treating the crude sodium carbolate from petroleum sources or an additional oxidation step may be introduced to remove any mercaptans.

2. Input Materials

Crude sodium carbolate

$\text{CO}_2$

$\text{H}_2\text{SO}_4$

Steam

3. Operating Parameters

Temperature - not given

pressure - not given

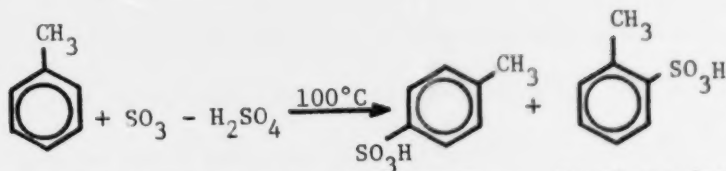
4. Utilities - not given

5. Waste Streams - Caustic soda may be released in wastewater; small quantities of phenolic bodies released to the air from distillation columns.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 434.

Toluenesulfonic Acids

1. Function - The sulfonation of toluene produces all three isomers (o, m and p). The para isomer is formed as the temperature of the reaction is increased. Sulfonating with oleum at low temperature produces a mixture of ortho and para sulfonic acids, the ortho isomer predominating. These isomers are separated either by converting to the sulfonyl chloride derivative (ortho-viscous oil; para-solid) or by crystallization.

The pure meta isomer is produced by sulfonating p-toluidine and diazotization of the product. The predominately para-isomer is made by raising the reaction temperature to 100°C.

2. Input Materials - Basis: 1 kg of toluenesulfonic acid

Toluene - 0.53 kg

Oleum - >0.46 kg.

3. Operating Parameters

Temperature: 100°C (212°F)

Pressure: 100 KPa (1 atm)

Catalyst: None

4. Utilities - Not given
5. Waste streams - No specific information was available. The usual sulfonation process is enclosed to prevent the emission of acid mists. Air pollution by mists can occur when storage vessels are loaded. The distillation may result in toluene vapor emissions.

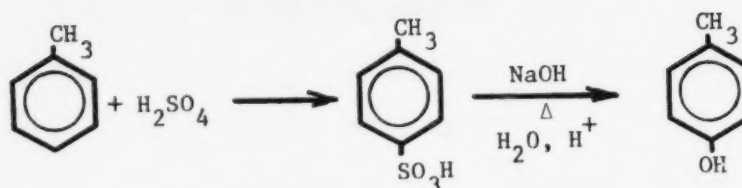
There will be a wastewater stream containing neutralized acid, probably as sodium sulfate. Some organic material will also be discharged into the waste stream (toluene and toluene sulfonic acid). The wastewater will arise from three sources: (1) air pollution control devices (scrubber); (2) condensate from the distillation; (3) diluted acid from the reactor.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Monsanto Research Corporation, Dayton, Ohio, Technomic Publishing, Co., Inc., Westport, Conn., 1975, p. 330.

Brooks, B. T., S. K. Kurtz and L. S. Schmerling, "The Chemistry of Petroleum Hydrocarbons," Vol. III, Reinhold Publishing Corp., New York, N.Y., 1955.

p-Cresol (from toluene)

1. Function - Only a small tonnage of p-cresol is produced synthetically by sulfonation of toluene. The sulfonation product is predominantly p-toluene sulfonic acid with a small amount of the o-isomer. Fusion with caustic soda and caustic potash at 330-360°C yields the alkali salts of the cresols from which they are recovered by neutralization and pure p-cresol is recovered by fractionation.
2. Input Materials

Toluene

Sulfuric acid

NaOH or  $\text{Na}_2\text{CO}_3$

Water
3. Operating Parameters

Not given
4. Utilities

Not given
5. Waste Streams - Small quantities of sulfuric acid and cresol would be expected to escape in waste waters and air.

|      |                                         |
|------|-----------------------------------------|
| Flow | 10.8 l/kg (1291 gal/10 <sup>3</sup> lb) |
| COD  | 23,800 mg/l                             |
|      | 256 g/kg (1b/10 <sup>3</sup> lb)        |



BOD<sub>5</sub>            11,400 mg/l  
                  123 g/kg (1b/10<sup>3</sup> lb)  
TOC                5,020 mg/l  
                  54 g/kg (1b/10<sup>3</sup> lb)

6. EPA Source Classification Code - None

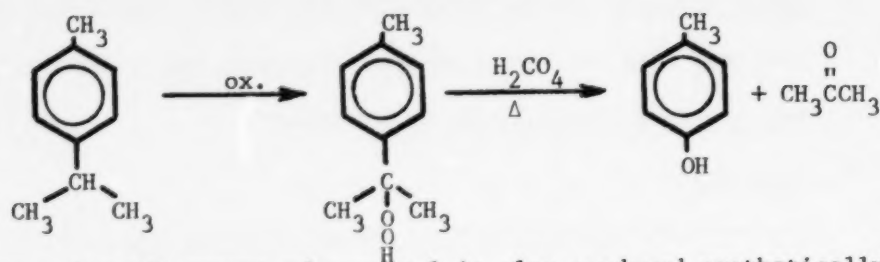
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 434.

Ibid, Supplement Volume (1971), p. 271

U.S. Patent 2,225,564 (Dec. 17, 1940).

Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corp., Park Ridge, N.J., 1974, p. 113-116.

p-Cresol (from p-cymene)

1. Function - A small amount of p-cresol is also produced synthetically by oxidation of p-cymene. The general tight supply of naval stores (from which p-cymene is isolated) and the recent high cost does not make this an economical starting material for the synthesis of p-cresol. The Hercules Powder Co. has alkylated toluene with propylene in the presence of  $\text{AlCl}_3$  to give a mixture of cymenes rich in the m- and p- derivatives. This mixture is treated with an oxygen-containing gas at 25-35°C in the presence of aqueous alkali and the resultant mixture of hydroperoxides is decomposed into cresols and acetone by treatment, in an alcohol solvent, with sulfuric acid at 65-85°C.

2. Input Materials

p-Cymene

 $\text{O}_2$ 

Alkali

 $\text{H}_2\text{O}$ 

Methanol

3. Operating Parameters

Hydroperoxidation - 25-35°C (77-95°F)

Decomposition - 65-85°C (149-185°F)

Pressure - Atmospheric

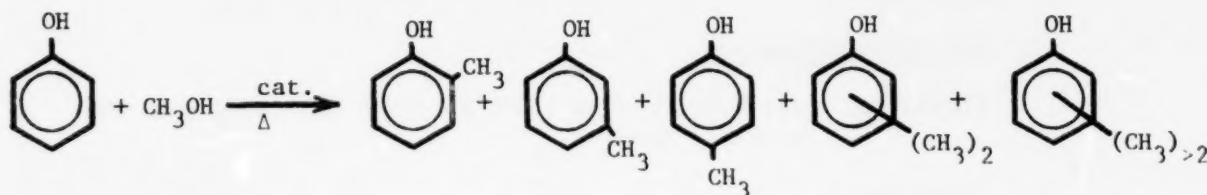
4. Utilities - Not given
5. Waste Streams - Waste water contains sodium hydroxide, p-cresol and acetone. The air vents may emit p-cymene and acetone.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 434.

Ibid., Supplement Volume (1971), p. 271.

Brit. Patent, 754,872 (Aug. 15, 1956).

p-Cresol, m-Cresol, o-Cresol, Xylenols  
and Higher Methylated Phenols



1. Function - Vapor-phase methylation of phenol with methanol over an aluminum catalyst yields, according to the conditions, different methylated phenol products. Careful control of the temperature and selection of different acidity silica - alumina catalysts permits some selectivity in methylation products. The ratio of mono- to poly-methylated products can be controlled by the ratio of methanol to phenol. The methyl group needed for the methylation of phenol may be derived from many different sources, e.g., methyl halides, methyl ethers, methyl amine. Co-catalysts may also be used to increase the selectivity in methylation. In 1965 Koppers Company started the first synthetic cresol plant which was soon followed by Consolidated Coal Co.

The pure cresols may be separated in a continuous fractional distillation. The similarity in the b.p. of the m- and o- isomers precludes their separation by this means. Azeotropic distillation with benzyl alcohol, selective solvent extraction or solid complex formation between the reagent and one of the cresol isomers are some of the techniques used in their separation.

2. Input Materials

Phenol

Methanol

3. Operating Parameters

Alkylation - Temperature from 175°C to 375°C depending upon the products desired.

4. Utilities

Not given

5. Waste Streams - Small quantities of phenol and methanol would be expected to escape in waste water as well as air.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, Vol. 6 (1965), p. 434.

Ibid., Supplement Volume (1971) p. 271.

British Patent 602,257 (May 24, 1948).

SECTION IV  
ETHYLENE

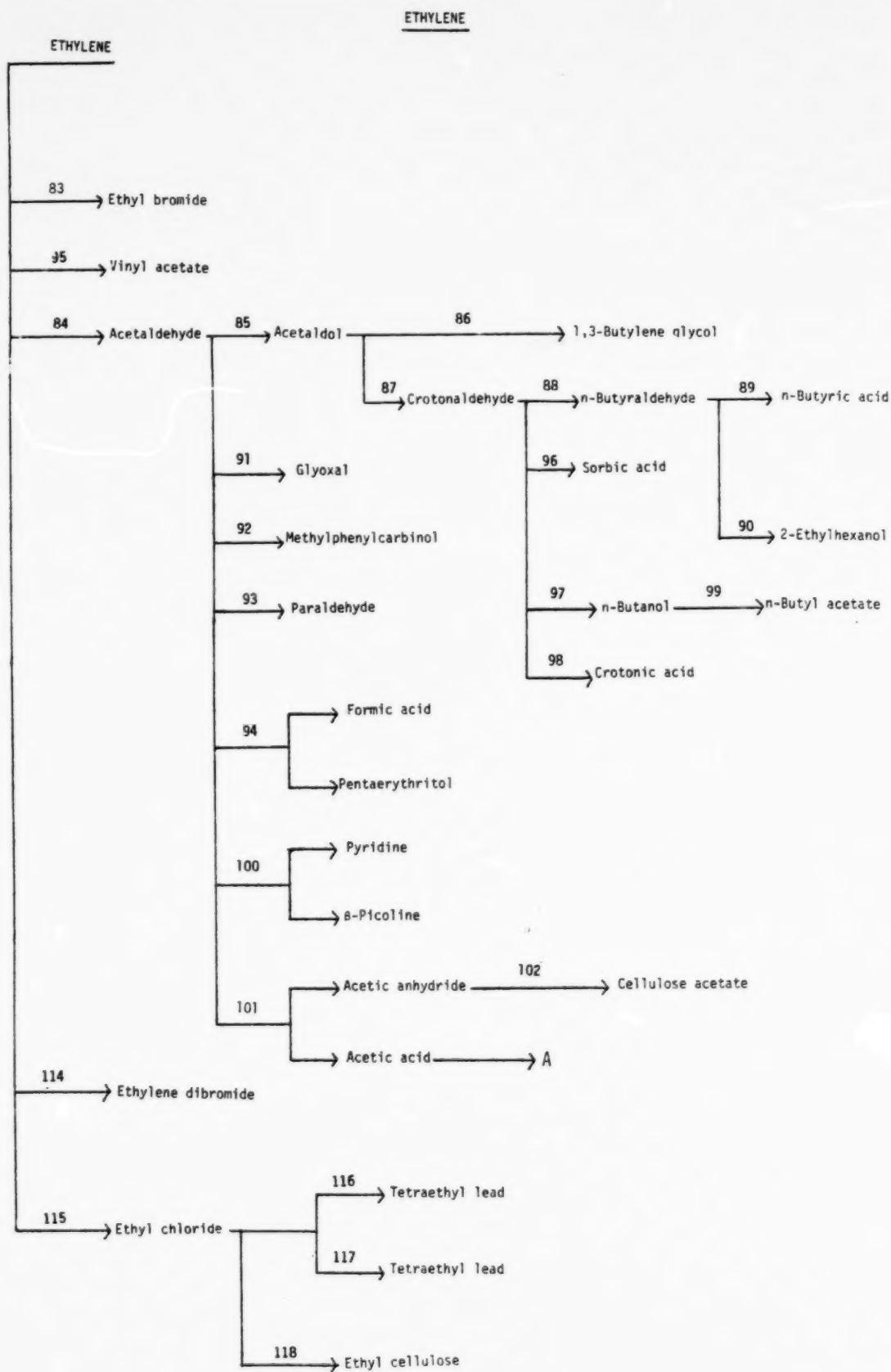


Figure 7. Ethylene Section Chemical Tree



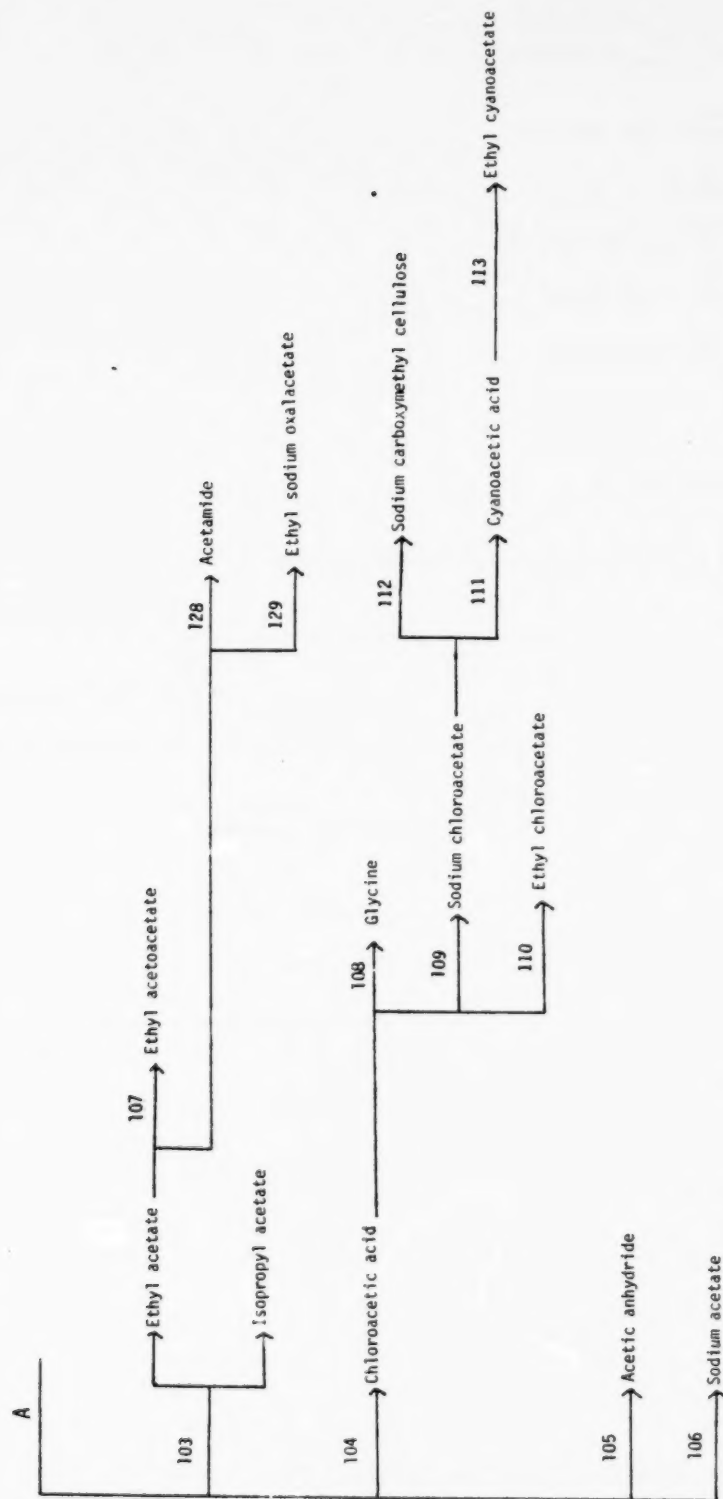


Figure 7. Ethylene Section Chemical Tree (Cont.)

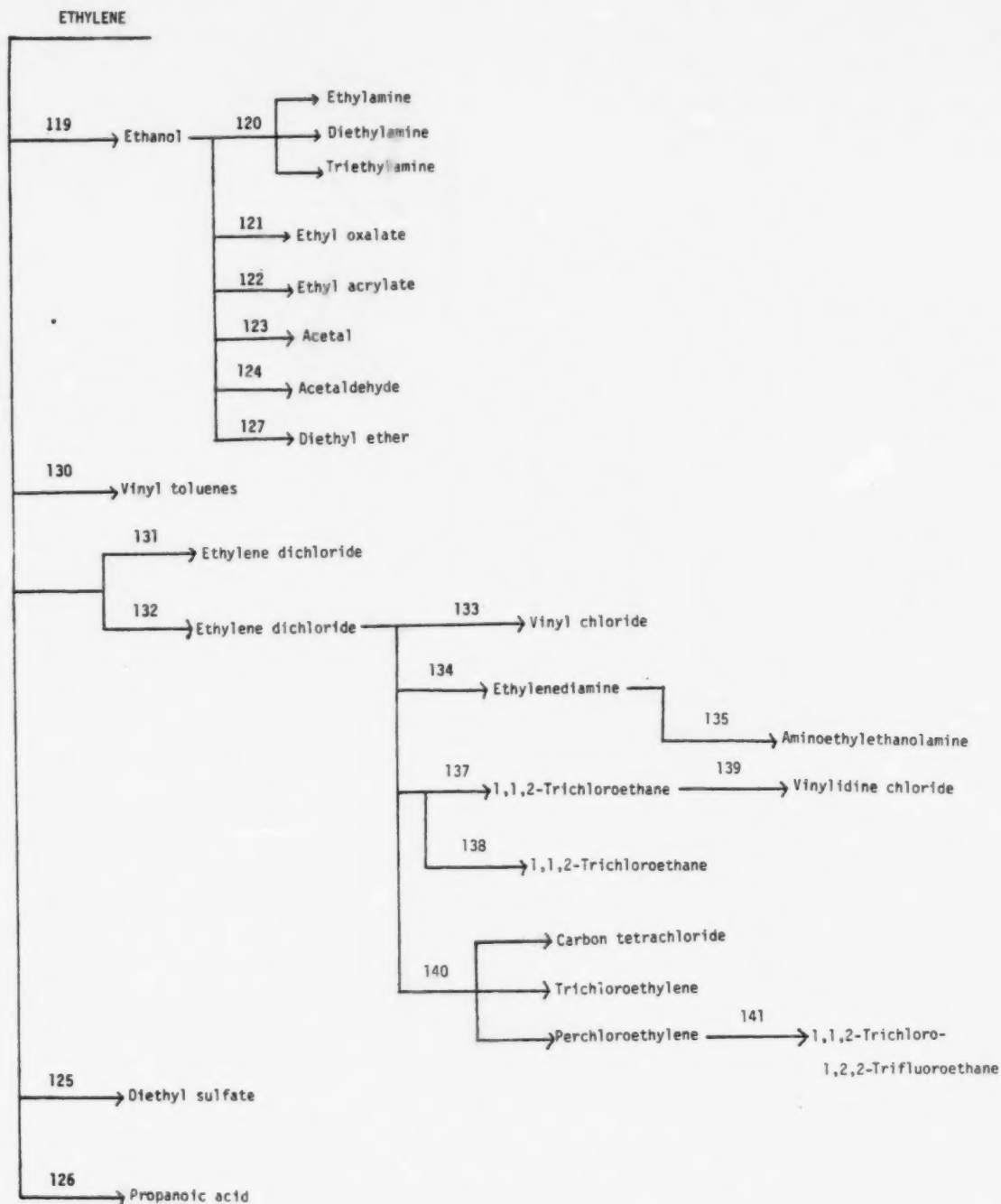


Figure 7. Ethylene Section Chemical Tree (Cont.)

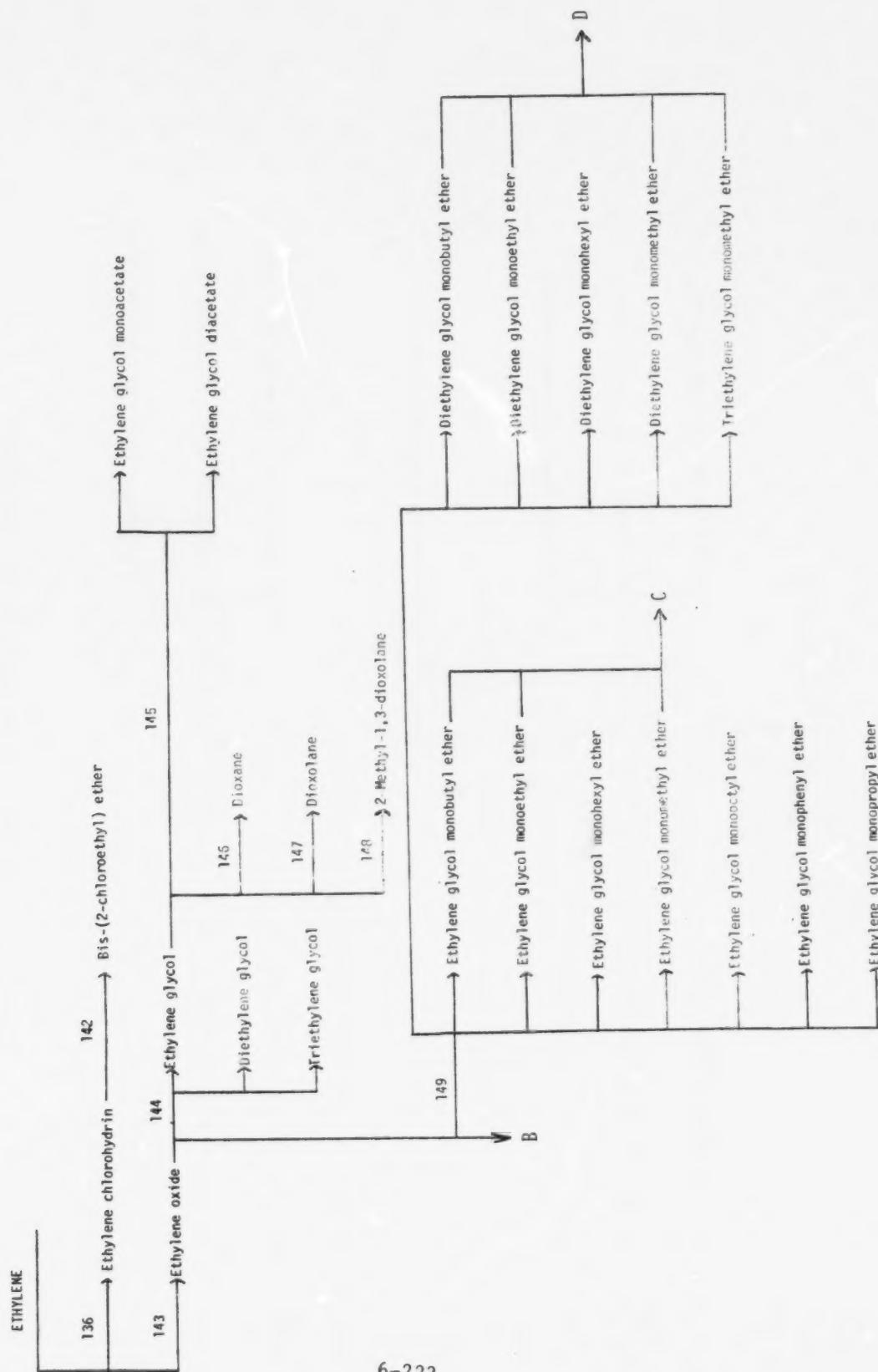


Figure 7. Ethylene Section Chemical Tree (Cont.)

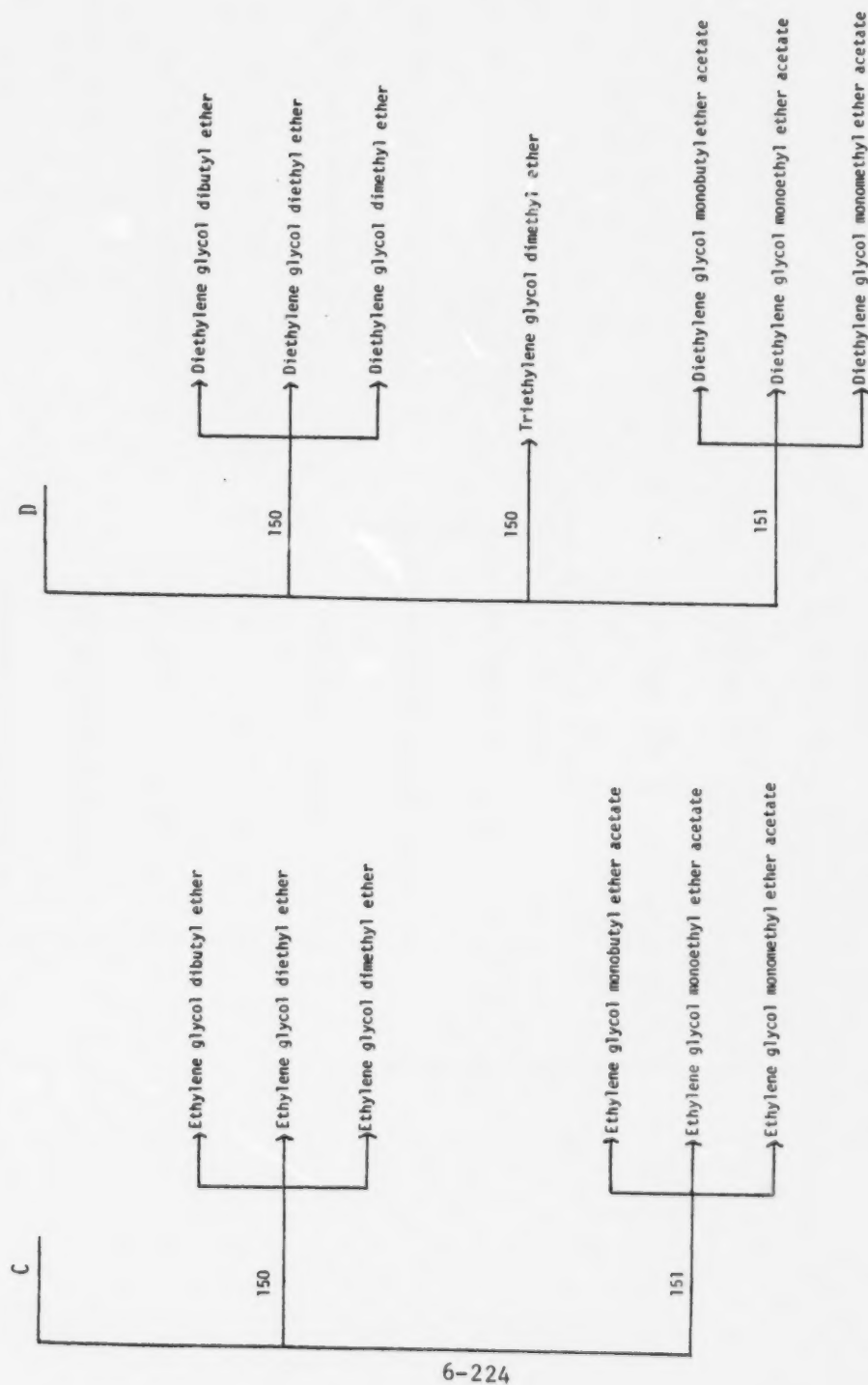


Figure 7. Ethylene Section Chemical Tree (Cont.)

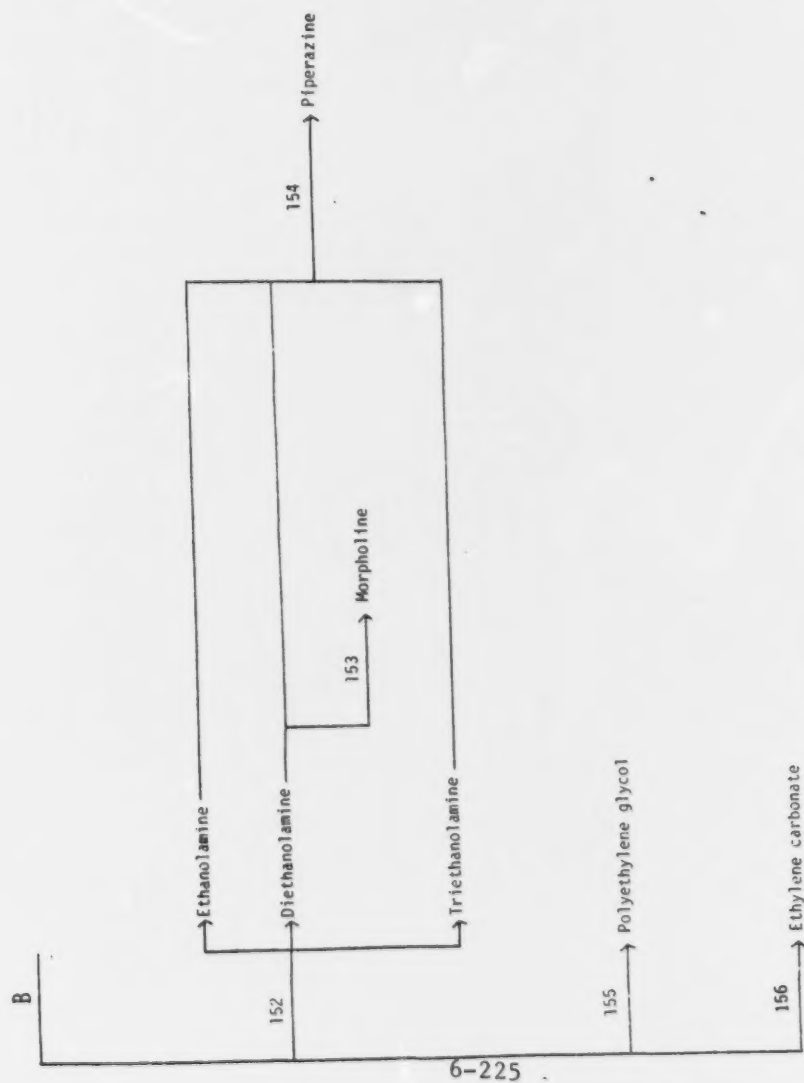


Figure 7. Ethylene Section Chemical Tree (Cont.)

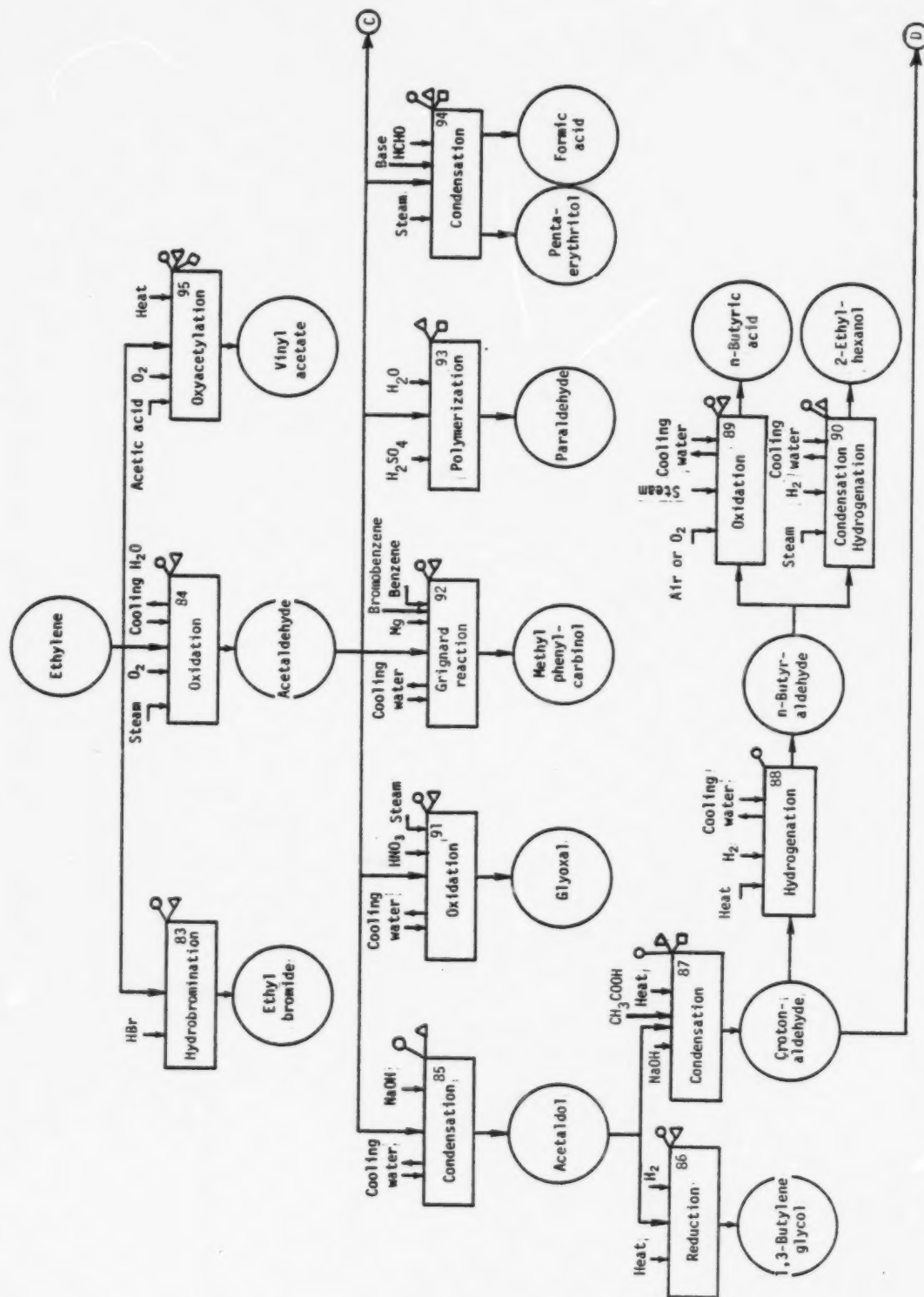


Figure 8. Ethylene Section Process Flow Sheet

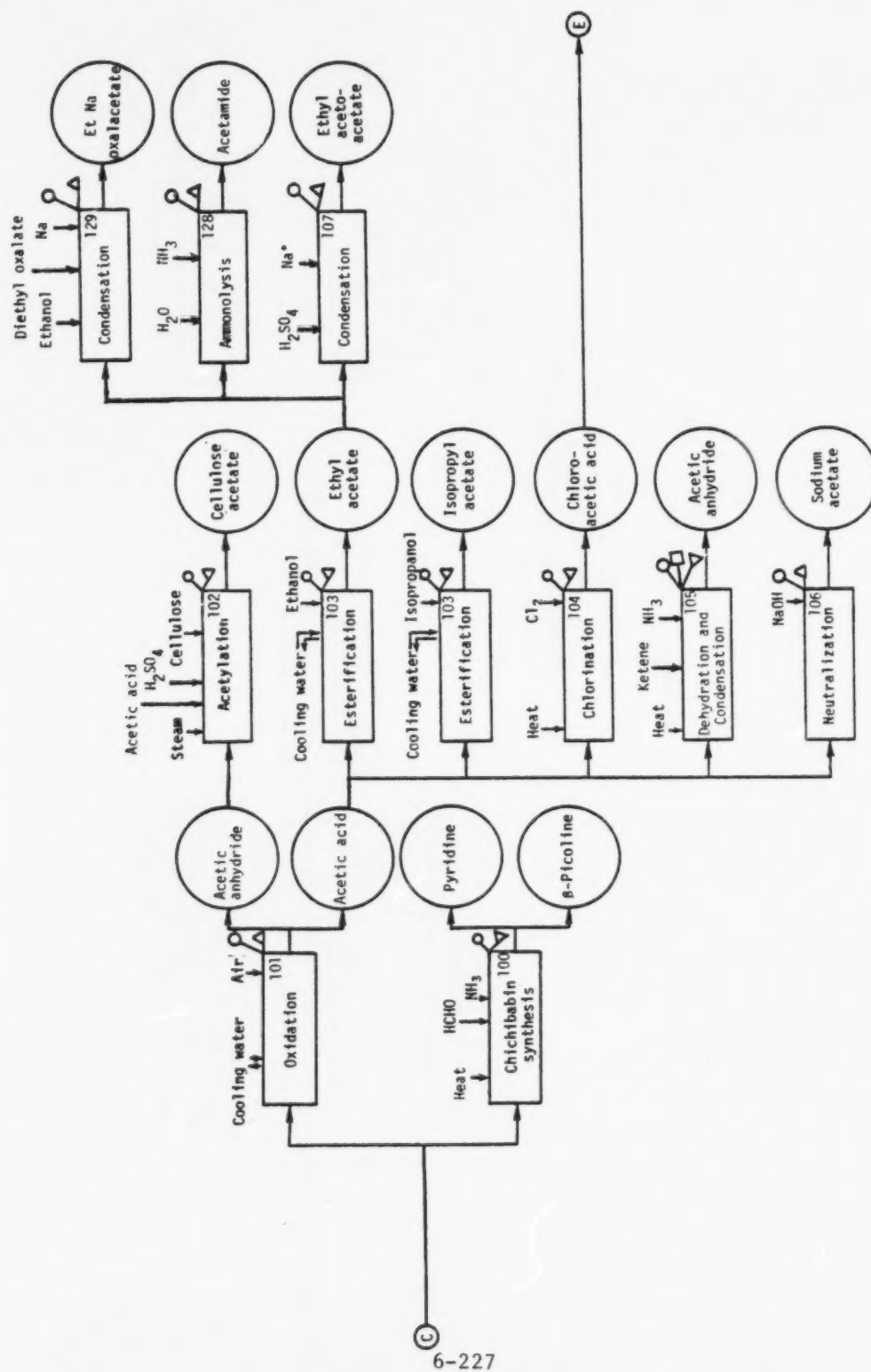


Figure 8. Ethylene Section Process Flow Sheet (Cont.)



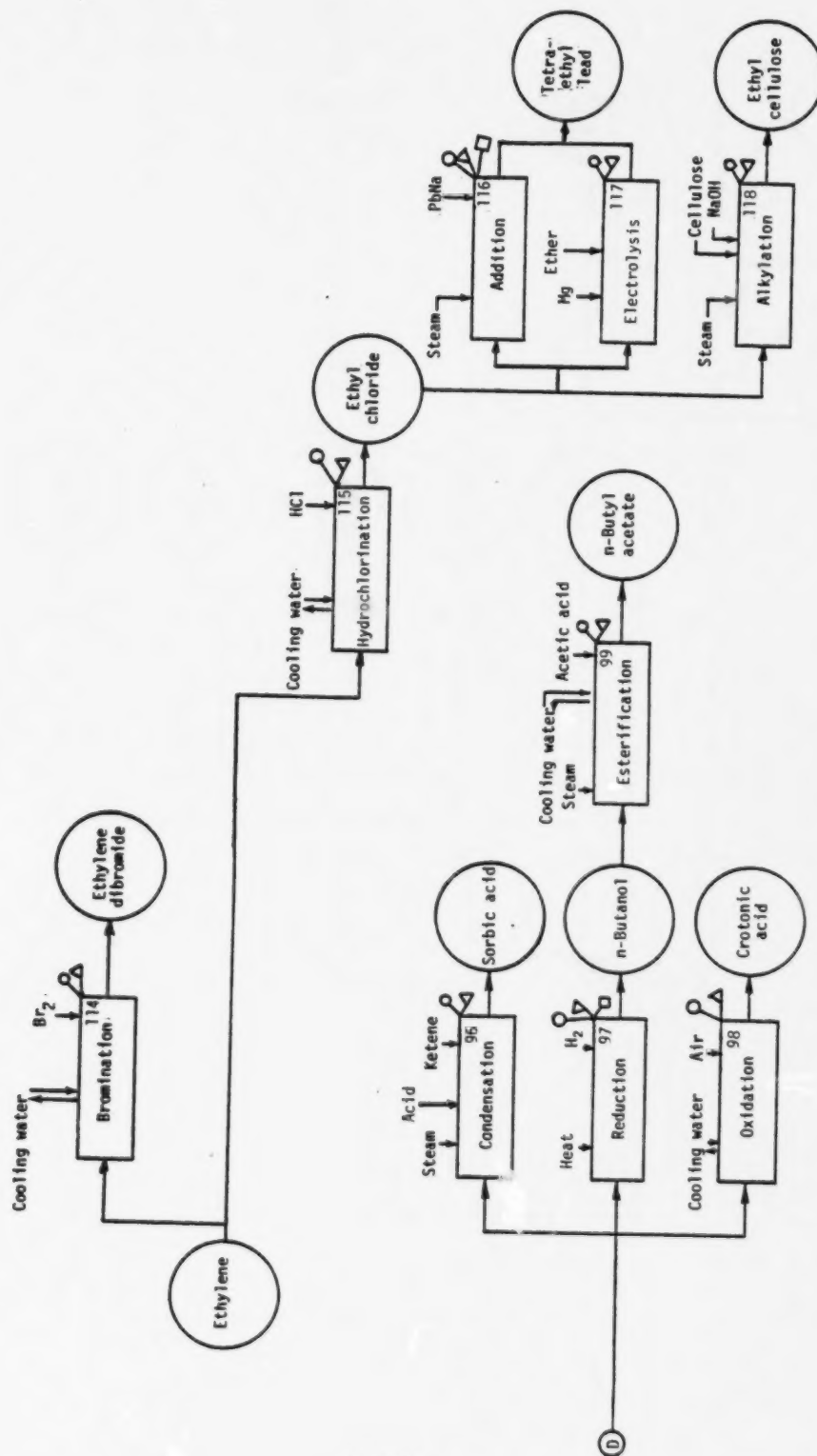


Figure 8. Ethylene Section Process Flow Sheet (Cont.)

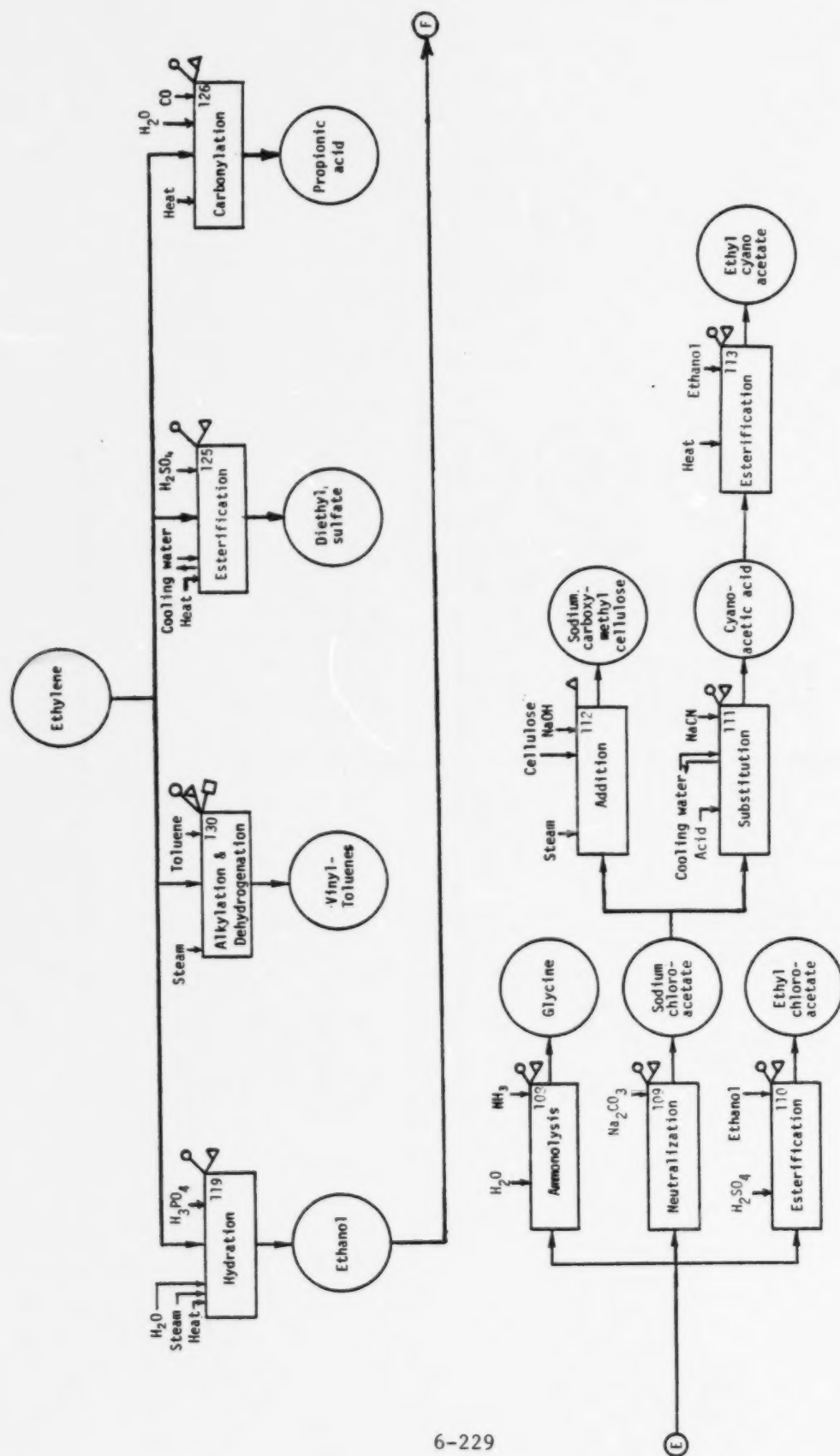


Figure 8. Ethylene Section Process Flow Sheet (Cont.)

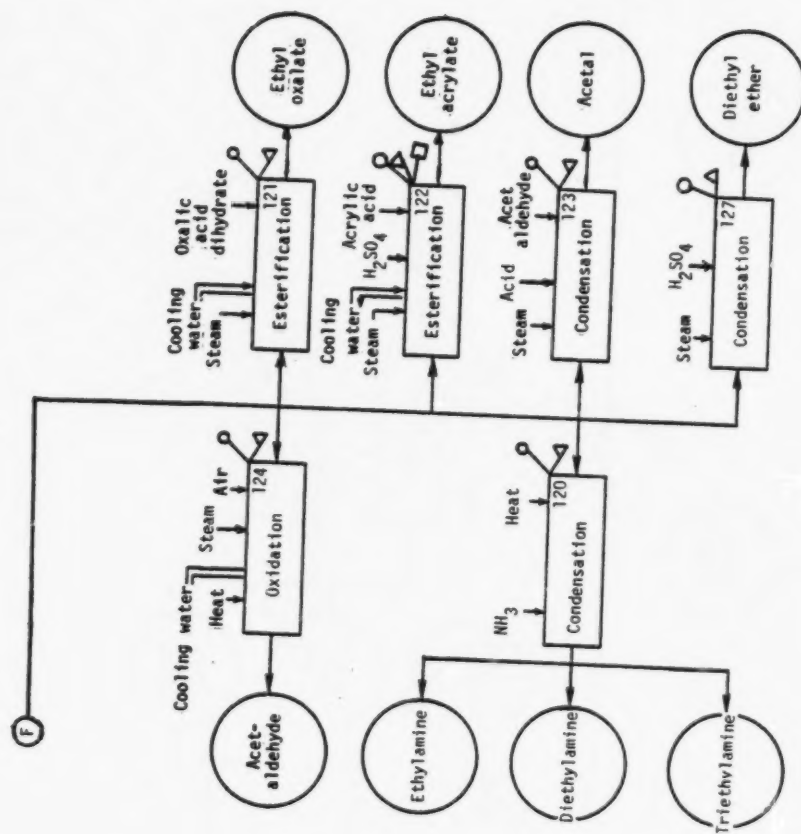


Figure 3. Ethylene Section Process Flow Sheet (Cont.)

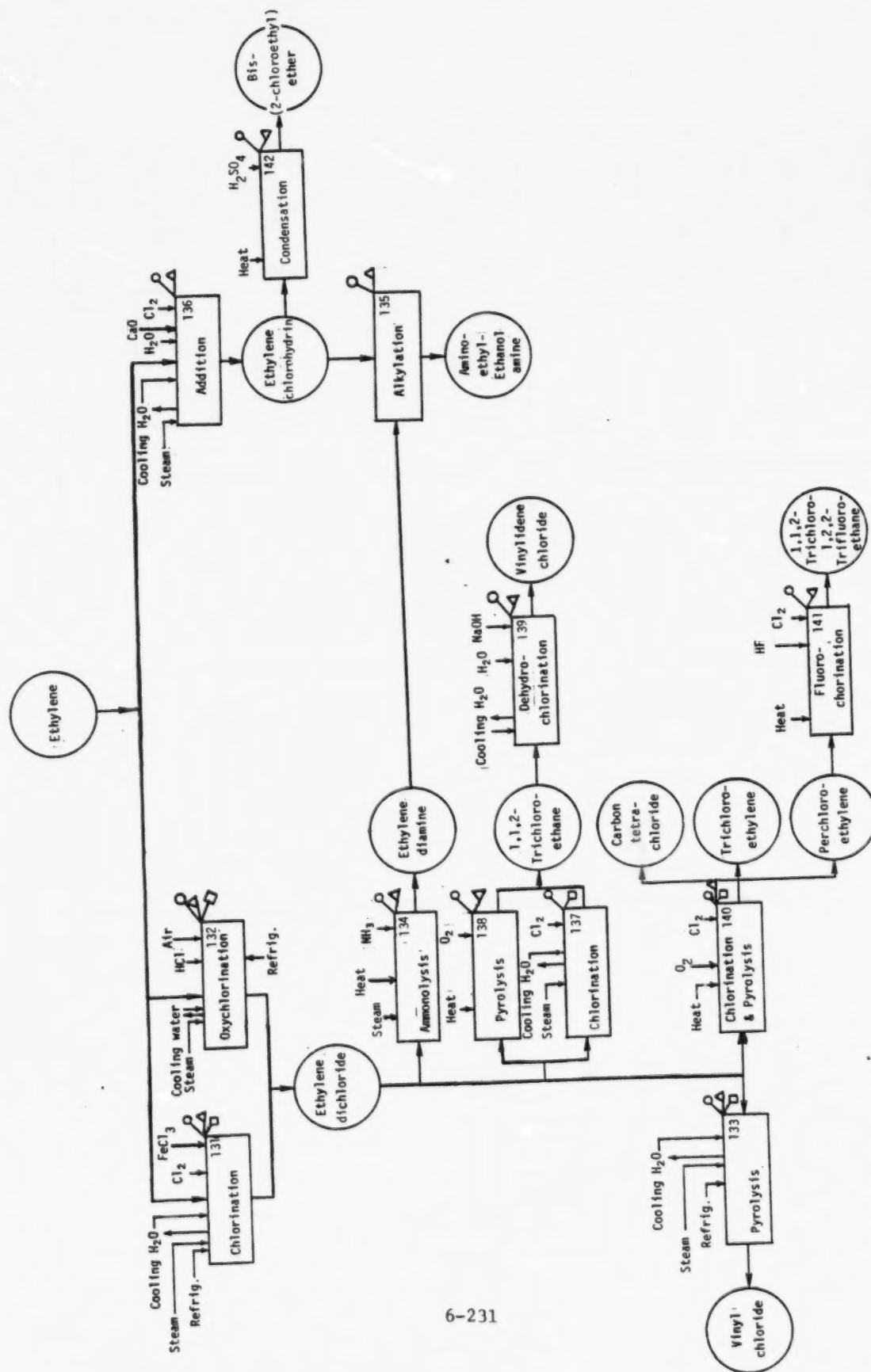


Figure 8. Ethylene Section Process Flow Sheet (Cont.)

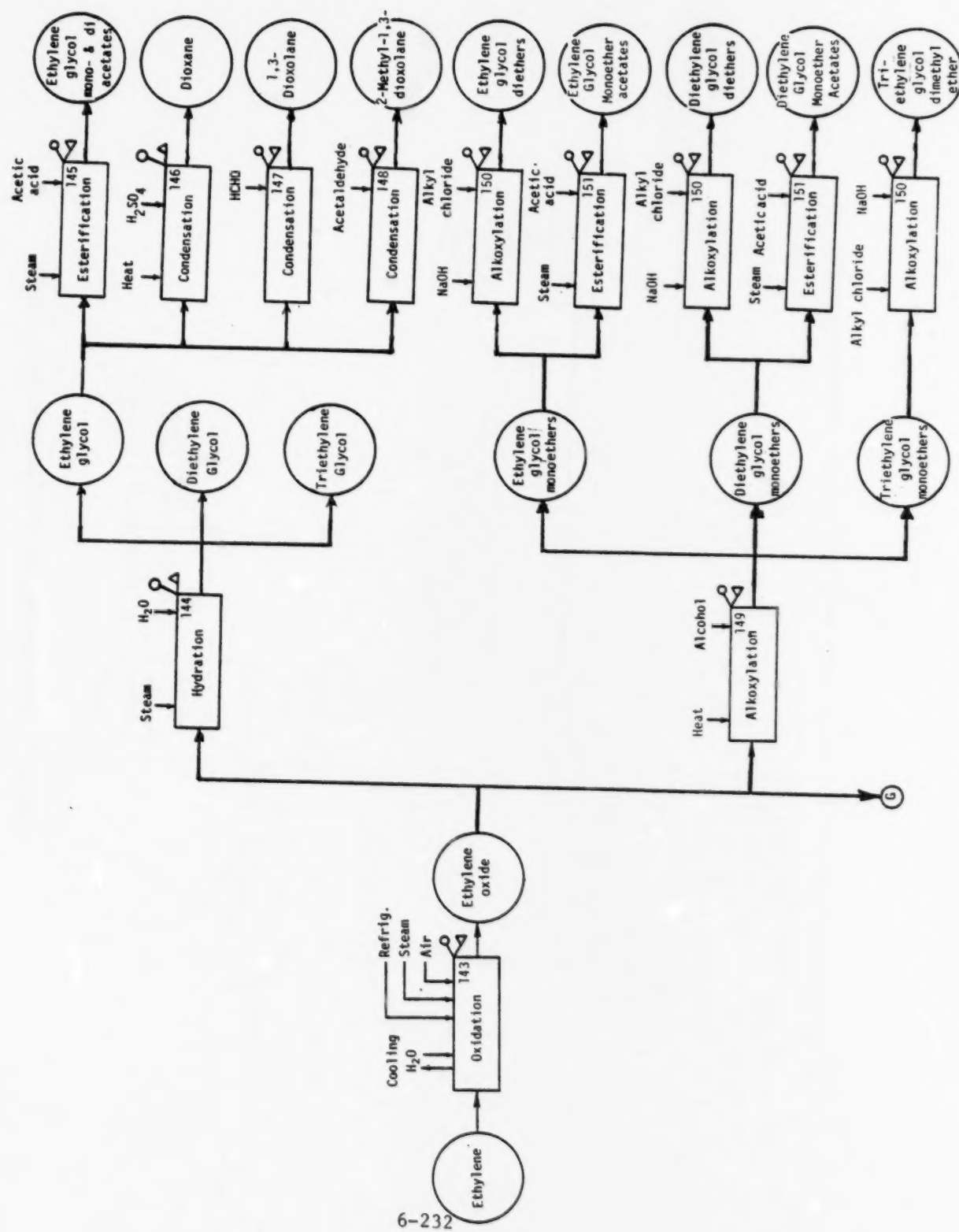


Figure 8. Ethylene Section Process Flow Sheet (Cont.)

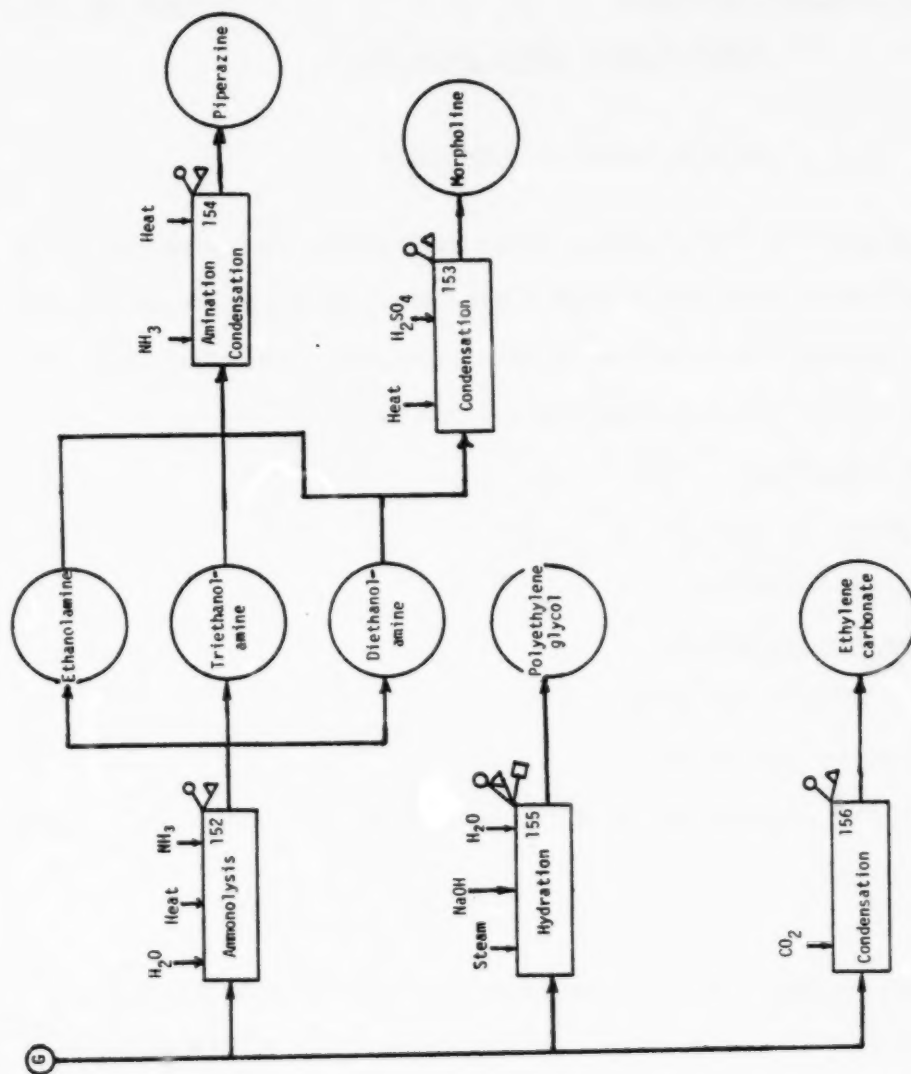
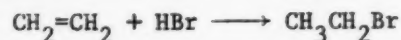


Figure 8. Ethylene Section Process Flow Sheet (Cont.)

Ethyl Bromide (from ethylene)

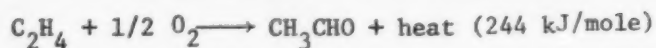
1. Function - In recent years, ethyl bromide has been produced by the vapor-phase reaction of high-purity ethylene and hydrogen bromide. The reaction is catalyzed by gamma radiation from cobalt-60. It may also be prepared from ethanol and HBr.
2. Input Materials  
Ethylene  
Hydrogen bromide
3. Operating Parameters  
Temperature: Not given  
Pressure: Not given  
Catalyst: Cobalt-60, as a source of gamma radiation
4. Utilities  
Not given
5. Waste Streams - Information on this process was too limited to evaluate its potential pollutant sources, but HBr and ethylene may leak out of the system.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 774.  
  
Shreve, R. N., Chemical Process Industries, 3rd Ed., McGraw-Hill Book Co., New York, N.Y., 1967, p. 793.



References (continued)

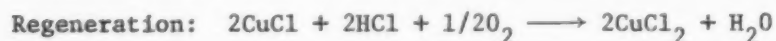
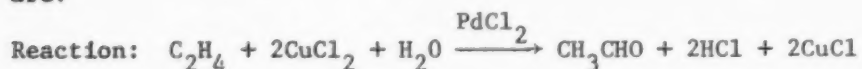
Hahn A. V., The Petrochemical Industry: Markets and Economics,

McGraw-Hill Book Co., New York, N.Y., 1970 p. 316.

Acetaldehyde (Wacker process)

1. Function - The Wacker process employs an aqueous catalyst solution of palladium chloride, promoted by copper chloride.

The catalyst acts as the oxygen carrier and causes selective conversion of ethylene to acetaldehyde. The reaction steps essentially are:



There are two basic process variations, depending upon such factors as oxygen cost, utilities prices, and available ethylene purity. In the single-stage process, pure oxygen is employed as the oxidant. The reactor effluent is condensed and water-scrubbed. Unreacted gas is recycled into the reactor. By-products and water are separated from the acetaldehyde product by distillation. Both the reaction and regeneration are effected at the same time.

In the two-stage process, the oxidant is air. The reaction is carried out with catalyst solution and ethylene in one reactor, and the regeneration is carried out with air in a separate reactor. Lower purity ethylene can be used with this version of the process. However, this process forms more by-products and requires high operating pressures.

The production of acetaldehyde by vapor phase oxidation of propane-rich LPG is considered obsolete.

2. Input Materials (per metric tonne acetaldehyde)

|                                                                                             | <u>Single-stage</u>     | <u>Two-stage</u>       |
|---------------------------------------------------------------------------------------------|-------------------------|------------------------|
| Ethylene 99.8 vol. %, kg                                                                    | 670                     | 670 <sup>*</sup>       |
| Oxygen, Nm <sup>3</sup>                                                                     | 275                     | -                      |
| Catalyst: PdCl <sub>2</sub> , g                                                             | 0.9                     | 0.9                    |
| CuCl <sub>2</sub> + 2H <sub>2</sub> O, g                                                    | 150                     | 150                    |
| HCl (100%) used as 30% aqueous solvent, kg                                                  | 4                       | 15                     |
| 3. <u>Operating Parameters</u>                                                              |                         |                        |
| Temperature, °C (°F)                                                                        | 130 (266)               | -                      |
| Pressure, kPa (atm)                                                                         | 294 (2.90)              | 784-883<br>(7.74-8.71) |
| 4. <u>Utilities</u>                                                                         |                         |                        |
| Cooling water (25°C), m <sup>3</sup>                                                        | 300                     | 200                    |
| Cooling water (12°C), m <sup>3</sup>                                                        | -                       | 12                     |
| Process water, m <sup>3</sup>                                                               | 6                       | -                      |
| Deionized water, m <sup>3</sup>                                                             | 3                       | -                      |
| Steam, metric ton                                                                           | 1.6                     | 1.2                    |
| Electric power, MJ (kWh)                                                                    | 754 (210)               | 300 <sup>**</sup>      |
| Credit for nitrogen (protection gas), Nm <sup>3</sup> (637 kPa)                             | -                       | 900                    |
| 5. <u>Waste Streams</u> - Purification section - acetaldehyde scrubber vent to flare (air). |                         |                        |
| Ethane:                                                                                     | 2.2 kg/Mg acetaldehyde  |                        |
| Ethylene:                                                                                   | 27.4 kg/Mg acetaldehyde |                        |
| Acetaldehyde:                                                                               | trace                   |                        |
| Methane:                                                                                    | trace                   |                        |
| Methyl chloride:                                                                            | trace                   |                        |

<sup>\*</sup> Ethylene of lower purity results in slightly higher consumption

<sup>\*\*</sup> Including air compression

Purification section - acetaldehyde stripper vent to flare (air)

Methyl chloride: 8.65 kg/Mg acetaldehyde

Acetaldehyde: trace

A typical Wacker process discharges about  $4.4 \text{ m}^3$  (1,200 gallons) of waste per ton of product. The chlorinated aldehydes are the principal contaminants in the waste streams which have a COD of approximately  $10 \text{ cg/m}^3$  (10,000 mg/l).

The two-stage process yields relatively small amounts of a rather concentrated waste water which must be pretreated before normal biodegradation. The single-stage yields considerably more of a more dilute waste water suitable for biodegradation.

6. EPA source classification code - None

7. References

Morse, P. L., "Acetaldehyde," Report No. 24, Stanford Research Institute, Menlo Park, California, April 1967.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollutational Problems Associated with Petrochemical Wastes," for FWPCA, Contract No. 14-12-461, February 1970.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 127.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," 54, November 1975, p. 100.

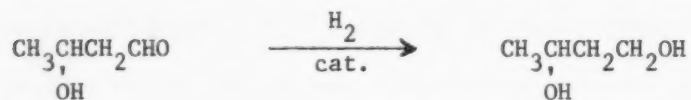
Jira, R., et al., "Hydrocarbon Processing," 55, March 1976, p. 99.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, N.J., 1974, p. 50,52.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 1,2.

Acetaldol

1. Function - Acetaldol is made from acetaldehyde via liquid-phase condensation at 10-25°C in the presence of dilute alkali. This process results in a 95% yield with about a 60% conversion.
2. Input Material  
Acetaldehyde: 1.05 kg/kg acetaldol, 107 kg/hr  
H<sub>2</sub>O: 20 kg/hr  
NaOH (20 g/l): 16 l/hr
3. Operating Parameters  
Temperature: 10-25°C (50-77°F)  
Pressure: not given  
Catalyst: 10% NaOH  
pH: 4-5 (by HCO<sub>2</sub>H)
4. Utilities - Not given
5. Waste Streams - Wastewater streams from acetaldehyde strippers may contain acetaldehyde, acetaldol, and dilute sodium hydroxide.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 1 (1963), p. 82.  
Ibid, Vol. 6 (1964), p. 446  
British Patent 630,904 (October 24, 1949).

1,3-Butylene Glycol (reduction of acetaldol)

1. Function - 1,3-Butylene glycol is produced by the catalytic hydrogenation of acetaldol. The hydrogenation can be effected with copper, platinum oxide, or several other catalysts, but preferably with Raney nickel. Pressures and temperatures of 4.83 MPa and 65 - 120°C are used.

Low-boiling materials are stripped off under reduced pressure from the hydrogenation product. The residue is then filtered to remove precipitated salts and catalyst, and is redistilled at low pressure to give pure 1,3-butylene glycol.

2. Input Materials - Basis - 1.68 kg 1,3-butylene glycol

Acetaldol (70%, 30% H<sub>2</sub>O): 2.67 kg

Hydrogen: 2.07 MPa (20.4 atm)

Ni catalyst: 0.500 kg

3. Operating Parameters

Temperature: 65 - 120°C (149-248°F)

Pressure: 4.83 MPa (47.7 atm)

Catalyst: Raney nickel, copper, platinum oxide

Reaction Time: 0.5 - 2 hrs

4. Utilities - not given

5. Waste Streams - No specific information was available. Waste gas from the strippers may contain quantities of ethanol, n-butanol,



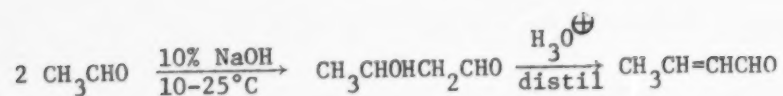
and other by-products, including 2,4-dimethyl-1,3-dioxane. Waste-water streams from filtering operations probably contain various salts and traces of catalyst. Heavy ends from distillation columns going to waste streams are mainly dibutylene glycols and their butyl ethers. Traces of acetaldehyde, acetaldol, and 1,3-butyleneglycol are probably present in all waste streams.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 10 (1966), p. 664.

Hancock, C. K., and Henson, D. D., "Industrial and Engineering Chemistry," Vol. 45 (1953), p. 629-632.

Crotonaldehyde

1. Function - Crotonaldehyde is most commonly made by the aldol condensation of acetaldehyde followed by dehydration. After the initial condensation has proceeded to 60% of completion, the acetaldol is treated with acetic or phosphoric acid and passed through a dehydration column at 95°C. Unreacted acetaldehyde is recovered and crotonaldehyde is separated overhead in almost quantitative yield.
2. Input Materials  
Acetaldol - 1.625 kg/kg crotonaldehyde
3. Operating Parameters  
Temperature - 10-25°C (50-77°F)  
Pressure - not given  
Catalyst - 10% NaOH
4. Utilities - not given
5. Waste Streams - There may be a wastewater stream. The likely pollutants are acetaldehyde, acetaldol, crotonaldehyde, and by-products. Heavy ends from distillation columns are usually incinerated.
6. EPA Source Classification Code - None
7. References  
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2", "Chemical Engineering", February 18, 1974, p. 126.

7. References

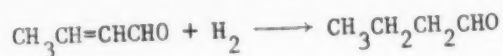
Hedley, W. H., et. al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 446.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 365.

Faith, W. L., et. al., Industrial Chemicals, 3rd Ed., John Wiley & Sons, New York, N.Y., 1965, p. 300, 301.

Waddams, A. L., Chemicals From Petroleum, 3rd Ed., John Murray Ltd., London, England, 1973, p. 79.

n-Butyraldehyde (hydrogenation of crotonaldehyde)

1. Function - In the production of n-butyraldehyde, crotonaldehyde is vaporized and passed through a converter with hydrogen. The converter tubes are packed with an activated nickel catalyst on an asbestos carrier.

Steam on the outside of the tubes is used to bring them to the reaction temperature, and is later replaced by water to carry heat away from the exothermic reaction.

The exit gases from the converter pass through condensers, and the hydrogen, which may be several times the theoretical amount, is recycled. The crude butyraldehyde is purified by fractionation.

2. Input Materials

Crotonaldehyde

Hydrogen

3. Operating Parameters

Temperature - 220-260°C (428-500°F)

Pressure - 207 kPa (2.04 atm)

Catalyst - Activated nickel supported on asbestos or copper chromite

Space velocity - 400/hr

4. Utilities - Not given

5. Waste Streams - Some crotonaldehyde and n-butyraldehyde may escape to the atmosphere during processing and purification. No specific information was available, however.

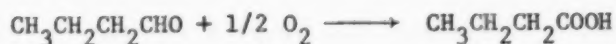
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 870,871.

U. S. Patent 2,825,743 (March 4, 1958).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition,  
Noyes Development Corp., Park Ridge, N.J., 1969, p. 132.

n-Butyric Acid (oxidation of n-butyraldehyde)

1. Function - Some butyric acid is prepared commercially by the oxidation of n-butyraldehyde. In this process, air or oxygen is passed into n-butyraldehyde in the presence of a catalyst such as manganese butyrate or a cobalt salt.

Yields of about 90% are possible over a wide range of temperatures.

2. Input Materials

n-Butyraldehyde - 0.91 kg/kg butyric acid

Air or oxygen

3. Operating Parameters

Temperature: 30-50°C (86-122°F)

Pressure: not given

Catalyst: 0.5% manganese butyrate

Cobalt salts

4. Utilities - Not given

5. Waste Streams - Although no information was available, some n-butyraldehyde and butyric acid are probably present in the reactor off-gas. Process slops may also be a source of these pollutants, as well as reaction by-products.

6. EPA Source Classification Code - None

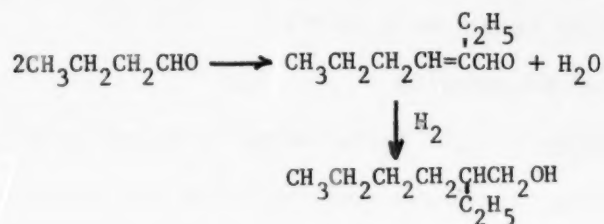
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 880.

Chemical Technology, Barnes and Noble Books, New York, N.Y.,  
Vol. 4 (1972), p. 426.

Goldstein, R. F., The Petroleum Chemicals Industry, 2nd Edition,  
John Wiley and Sons, New York, N.Y., 1958, p. 331.



2-Ethylhexanol (from n-butyraldehyde)

1. Function - 2-Ethylhexanol is produced by the aldol condensation of n-butyraldehyde, which can be derived from propylene via the oxo-process or from acetaldehyde via ethylene. The oxo process is the preferred route. The C<sub>8</sub> aldehyde formed is then hydrogenated to 2-ethylhexanol.

In the aldol process, dimerization is allowed to proceed without the separation of the C<sub>4</sub> aldehydes. The C<sub>4</sub> and C<sub>8</sub> aldehydes from the oxo step are hydrogenated at a temperature of approximately 150°C and a pressure of 180 atm (18 MPa) in the presence of a nickel catalyst. Gas-liquid separation yields 2-ethylhexanol with isobutyl alcohol as a byproduct.

2. Input Materials - Basis: 1 metric tone 2-ethylhexanol

n-Butyraldehyde - 1300 kg

Hydrogen - 360 m<sup>3</sup>

Nickel catalyst - 1 kg

3. Operating Parameters

Aldolization:

Temperature - 60-130°C (140-266°F)

Pressure - 0.3-1.0 MPa (2.96-9.87 atm)

Hydrogenation:

Temperature - 150° (302°F)

Pressure - 18 MPa (180 atm)

4. Utilities - 0.72 kg/sec capacity

Cooling water -  $32 \text{ dm}^3/\text{sec}$

Steam - 0.45 kg/sec at 1.14 MPa

Power - 447 KW capacity

5. Waste Streams - Light hydrocarbons from hydrogenation - 113.5 kg/Mg.

High boiling oxygenated compounds from the condensation of aldehydes and alcohols. Butyraldehyde 58.5 kg/Mg product.

6. EPA Source Classification Code - None

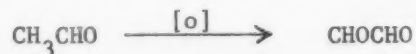
7. References

Hedley, W. H., et al., "Potential Pollutants from Petrochemical Processes," Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 14 (1963), p. 373-389.

Waddams, A.L., Chemicals From Petroleum 3rd Edition, John Wiley & Sons, (1973) p. 205.

Lowenheim, F. A. and Moran, M. K., "Industrial Chemicals," 4th Edition, John Wiley & Sons, New York, N.Y., (1975), p. 413-417.

Glyoxal (oxidation of acetaldehyde)

1. Function - Recently, glyoxal has been produced by the nitric acid oxidation of acetaldehyde in an autoclave. Previously the catalytic vapor-phase oxidation of ethylene glycol had been the standard commercial process. The product is washed with  $\text{NaHSO}_3$  and precipitated from  $\text{EtOH}/\text{H}_2\text{O}$ .
2. Input Materials - Basis - 0.70 kg glyoxal  
Acetaldehyde: 0.783 kg  
 $\text{SeO}_2$  (or  $\text{HNO}_3$ ): 28 g
3. Operating Parameters  
Temperature:  $80^\circ\text{C}$  ( $176^\circ\text{F}$ )  
Reaction Time: 2 hrs
4. Utilities - not given
5. Waste Streams - The information available on current production techniques was not sufficient to warrant a discussion of possible pollutant sources. As in all oxidation processes, reactants, products, and by-products may be emitted as a result of process slops.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 1 (1963), p. 80.

Ibid, Vol. 10 (1966), p. 646.

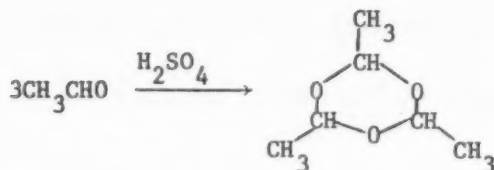
Riley, H. L., et al., J. Chem. Soc., 1932, p. 1875-1883.

Methyl Phenylcarbinol (from acetaldehyde)

1. Function - One method of synthesizing methylphenylcarbinol involves the addition of acetaldehyde to a Grignard reagent prepared from bromobenzene.
2. Input Materials  
Acetaldehyde  
Bromobenzene  
Ether (solvent)  
Magnesium  
Water
3. Operating Parameters  
Temperature: reflux temperature of solvent  
Pressure: 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Air - ether and bromobenzene vapors.  
Water - magnesium salts  
solid - unreacted Mg turnings and tarry materials.
6. EPA Source Classification Code - None

7. References

Horning, E. C., Organic Synthesis, John Wiley and Sons, New York,  
N.Y., Collective Vol. III (1955), p. 200-201.

Paraldehyde

1. Function In the presence of sulfuric acid, acetaldehyde rapidly polymerizes to paraldehyde, the trimer. The crude trimer is washed with water to remove monomer and the acid catalyst, and dried. Distillation separates the pure paraldehyde. In the absence of acid catalyst the trimer suffers no depolymerization on distillation or storage. Acetaldehyde can be regenerated readily by heating gently and distilling the paraldehyde in presence of acid catalyst.
2. Input Materials  
Acetaldehyde - 1.05 kg/kg paraldehyde
2. Operating Parameters  
Temperature (distillation) - 124°C (255°F)  
Pressure - 101 kPa (1 atm)  
Catalyst -  $\text{H}_2\text{SO}_4$
4. Utilities - Not given
5. Waste Streams - Waste water probably contains traces of acetaldehyde and sulfuric acid.
6. EPA Source Classification Code - None

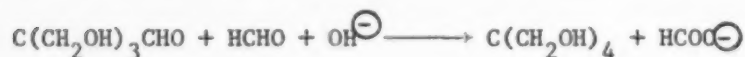
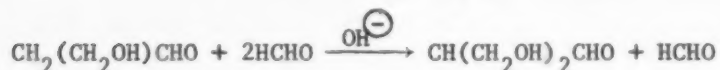
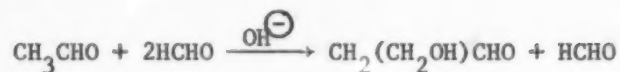


7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 81.

K. C. Frisch, High Polymers, Vol. XXVI, "Cyclic Monomers," John Wiley &  
Sons, 1972, p. 124.

Brandrup, J. and Goodman, M, Macromolecular Synthesis, Vol. 3, John  
Wiley & Sons, New York, N.Y., 1967, p. 74.

Pentaerythritol

1. Function - Pentaerythritol is made by reacting formaldehyde and acetaldehyde in molar ratios ranging from 4:1 to 10:1. The reaction is carried out in the presence of lime or caustic soda at near ambient temperatures and pressures.

The reaction sequence involves three identical aldol condensations in which the alkali acts as a catalyst, followed by a cross-Canizzaro reaction in which the condensation takes place.

Sodium carbonate is added to the reaction mixture to precipitate calcium ions in solution. The reaction mixture, which contains pentaerythritol, polypentaerythritols, sodium formate, and suspended calcium carbonate, is then filtered and passed through ion exchange and fractional distillation columns to obtain the final product. The yield is high, with about 88% of the product occurring as pentaerythritol, 10% as dipentaerythritol, and most of the remainder as tri-pentaerythritol. The sodium formate is commonly treated with sulfuric acid to give formic acid as a by-product.

2. Input Materials - Basis - 1 metric ton pentaerythritol

Acetaldehyde - 383 kg (844 lbs)

Formaldehyde - 3175 kg (7000 lbs)

Calcium hydroxide or sodium hydroxide 1050 kg (2315 lbs)

Sodium carbonate

Acid (formic) - 600 kg (1323 lbs)

3. Operating Parameters

Temperature: 15-50°C (59-122°F)

Pressure: 101 kPa (1 atm)

Catalyst:  $\text{Ca(OH)}_2$  or NaOH

Reaction Time: 3.5 hrs

4. Utilities

Not given

5. Waste Streams

Calcium carbonate precipitator (solid)

Calcium carbonate

Triple effect evaporator and vacuum crystallizer (air)

Air streams may contain unreacted acetaldehyde and formaldehyde,  
as well as some organic, side products (methanol and ethanol).

Vacuum crystallizer (water)

Water streams contain sodium formate which is usually recovered as  
formic acid. Inorganic sodium salts are then the final waste product.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 7," "Chemical Engineering," June 24, 1974, p. 155, 156.

7. References (continued)

Hedley, W.H., et a., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 590, 591.

U.S. Patent 2,612,526 (September 30, 1952).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969 , p. 508.

Lowenheim, F. A. and Moran, M.K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975 , p. 598, 599.

Vinyl Acetate (vapor-phase reaction of ethylene)

1. Function - The most common route to vinyl acetate involves a vapor-phase oxyacetylation using ethylene, acetic acid, and oxygen. The reaction takes place at 175-200°C and 485-965 kPa (70-140 psi) over a supported palladium catalyst. The conversion per pass is about 10% ethylene, 20% acetic acids, and 60% oxygen.

The reaction mixture is partly condensed after leaving the reactor and separated into liquid and gas phase. The gases are recycled via scrubbers in which vinyl acetate and carbon dioxide are removed. The liquid condensate is fed to the distillation train where light ends, mainly acetaldehyde, water, and polymers are removed from the purified vinyl acetate. Acetic acid is recycled to the reactor.

The overall yield is 91% vinyl acetate, 8% carbon dioxide, and 1% by-product, with better than 99% recovery of ethylene and acetic acid. The liquid-phase route to vinyl acetate from ethylene has not been a success.

2. Input Materials

Ethylene - 0.36 kg/kg vinyl acetate

Acetic acid - 0.77 kg/kg vinyl acetate

Oxygen - 0.20 kg/kg vinyl acetate

3. Operating Parameters

Temperature - 175-200°C (347-392°F)

Pressure - 70-140 psi - 483-965 kPa (4.8-9.5 atm)

Catalyst - supported palladium catalyst with small amount of potassium acetate (485-965 kPa)

4. Utilities - Not given

5. Waste Streams - Waste gases from the scrubbers may contain traces of ethylene, acetic acid, vinyl acetate, acetaldehyde, and other by-product gases. Heavy ends from distillation columns include polymers and mixed aldehydes.

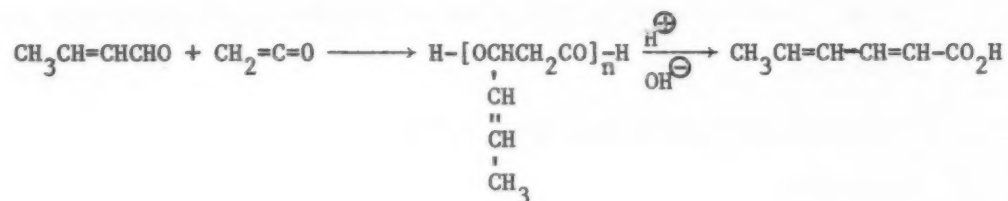
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 9," "Chemical Engineering," August 5, 1974, p. 98.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 862-867.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Wiley and Sons, New York, N.Y., 1973, p. 111.

Sorbic Acid (from crotonaldehyde)

1. Function - Crotonaldehyde and ketene react in the presence of a catalyst to form a polyester of 3-hydroxy-4-hexenoic acid.

The polymer intermediate may be isomerized to sorbic acid in acid or alkaline media. The crude sorbic acid is purified by codistillation under vacuum with an organic solvent having the same general distillation range.

Sorbic acid may also be manufactured by oxidation of 2,4-hexadienal.

2. Input Materials

Crotonaldehyde

Ketene

3. Operating Parameters

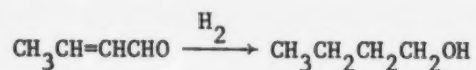
Temperature: not given

Pressure: not given

Catalysts: Reaction step - usually zinc carboxylic salts. Isomerization step - acid or base.



4. Utilities - Not given
5. Waste Streams - Waste water streams from the purification section may include acid or base catalysts, spent reaction catalysts, and distillation solvents in addition to traces of crotonaldehyde and sorbic acid.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 18 (1969), p. 590-591.

n-Butanol (from crotonaldehyde)

1. Function - The reduction of crotonaldehyde to n-butanol accounts for approximately 20% of the n-butanol produced in the United States. The reduction is accomplished by the vapor phase hydrogenation over a reduced nickel-chromium catalyst at 180°C and 207 kPa.

Precursor steps may include ethanol or ethylene to acetaldehyde, acetaldehyde to acetaldol, and acetaldol to crotonaldehyde.

2. Input Materials

Crotonaldehyde - 1.04 kg/kg n-butanol

Hydrogen

3. Operating Parameters

Temperature - 180°C (356°F)

Pressure - 207 kPa (30 psi) (2 atm)

Catalyst - Nickel-Chromium

4. Utilities - Not given

5. Waste Streams - The wastewater stream from the stripper may contain some n-butanol and crotonaldehyde. Heavy ends from distillation columns are usually incinerated.

6. EPA Source Classification Code - None

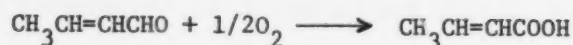
7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

7. References (continued)

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 826.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975 , p. 658-660.

Crotonic Acid

1. Function - Crotonic acid is prepared commercially by the catalytic oxidation of crotonaldehyde with air. The catalyst is a copper acetate-cobalt acetate mixture, about 0.5 - 1.0% by weight of the total charge, and the temperature is held between 35 - 50°C.

Percrotonic acid may be an immediate product of this process. In the continuous process, crotonaldehyde and catalyst solution are combined with an inert organic diluent such as benzene, methyl acetate, acetone, or methyl ethyl ketone in about equal volume and pumped into the oxidation kettle. Air is bubbled in, while the crude product is drawn off continuously. The diluent and unreacted crotonaldehyde are distilled off and returned to the process, while the crude crotonic acid is fractionated under reduced pressure.

2. Input Materials - Basis - 157 parts crotonic acid

Crotonaldehyde: 226 parts

Air

Organic diluent (MeOAc): 245 parts

Catalyst  $[\text{Cu}(\text{OAc})_2]$ : 2.70 parts

$[\text{Co}(\text{OAc})_2]$ : 0.45 parts

3. Operating Parameters

Temperature: 35 - 50°C (95-122°F)

Pressure: not given

Catalyst: Copper acetate - cobalt acetate

4. Utilities - The principal pollutant source from this process should be the waste stream from the purification section, containing acetic acid, formic acid, other reaction by-products, and traces of crotonaldehyde, crotonic acid, organic diluent, and spent catalyst.

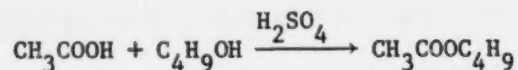
6. EPA Source Classification Code - None

7. References

U.S. Patent 2,413,235 (December 24, 1946).

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 6 (1965), p. 454, 455.

British Patent 595,170 (November 27, 1947).

n-Butyl Acetate

1. Function - Butyl acetate's manufacture involves the classic reaction between butanol and dilute acetic acid, catalyzed by 0.1%  $\text{H}_2\text{SO}_4$ . Butyl acetate, which boils at 126.5°C forms with butanol and water, a ternary azeotrope which boils (89.4°C) below a binary azeotrope that butyl acetate forms with butanol. The ternary azeotrope separates into two layers on condensing - 81% ester, 13% butanol, and 6% water in the tops and 1% ester, 3% butanol, and 96% water in the bottoms. These fortunate circumstances ease removal of the water-of-reaction, so that low concentrations of acetic acid in water work extremely well as feed to the process.

A 10% excess of the stoichiometric requirement of butanol is fed to this reaction.

2. Input Materials

n-Butanol - 0.98 kg/kg (1,969 lb/ton) n-butyl acetate

Acetic acid - 0.81 kg/kg (1,620 lb/ton) n-butyl acetate

3. Operating Parameters

Temperature: 90°C (194°F)

Pressure: not given

Catalyst: 0.1%  $\text{H}_2\text{SO}_4$

4. Utilities

Not given

5. Waste Streams

Separator (water)

The separator may discharge a water stream containing n-butyl acetate, n-butanol, acetic acid, and sulfuric acid and may be treated to recover some of these materials.

Separator (air)

The separator air vent could emit n-butyl acetate and n-butanol vapors.

Purification section

No information was available on this section, but the same types of pollutants would be expected.

6. EPA Source Classification Code - None

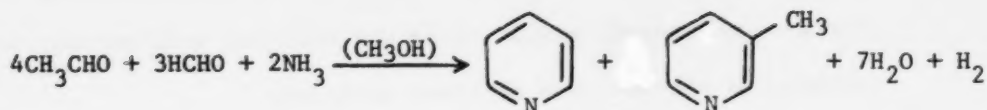
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 126.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 173, 174.



Pyridine and  $\beta$ -Picoline

1. Function - Pyridine and beta-picoline are co-produced by the vapor phase reaction of acetaldehyde, ammonia, and formaldehyde. The formaldehyde is usually added in excess to inhibit the formation of alpha- and gamma-picoline, but mixtures of formaldehyde and methanol are also used.

In both process variations, the reactants are vaporized and passed through a fluid-catalyst-type reactor containing a fluidized catalytic bed of silica-alumina catalyst. The reaction is carried out at 250 - 500°C and atmospheric pressure.

The crude product is fractionated to obtain pyridine and 3-picoline. Typical yields based on acetaldehyde feed are 35% for pyridine and 27% for beta-picoline.

2. Input Materials - Basis - 47 parts pure mixed product  
acetaldehyde: 62 parts (6.37 kg/kg pyridine; 7.01 kg/kg 3-picoline)  
ammonia: 1 part  
formaldehyde: 67 parts  
methanol (in some process variations): 32 parts
3. Operating Parameters  
Temperature: 250 - 500°C (482-932°F)  
Pressure: 101 kPa (1 atm.)  
Catalyst: Alumina-silica (13%  $\text{Al}_2\text{O}_3$ , 87%  $\text{SiO}_2$ )
4. Utilities - not given

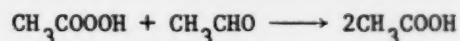
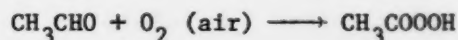
5. Waste Streams - Waste gases from the purification section may contain formaldehyde, ammonia, acetaldehyde, various amine by-products, and methanol, if used.

6. EPA Source Classification Code - None

7. References

U.S. Patent 2,807,618 (September 24, 1957).

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 16 (1968), p. 781, 785.

Acetic Anhydride and Acetic Acid

1. Function - Acetic acid and acetic anhydride are prepared primarily by the catalytic oxidation of acetaldehyde. In this process, the peracetic acid formed by the initial oxidation is allowed to react with an excess of acetaldehyde to form the anhydride, as well as acetic acid.

Copper, cobalt, or manganese acetate catalysts give selectivity to anhydride formation. Entraining agents such as ethyl acetate further enhance this conversion by removing the water of reaction.

| 2. <u>Input Materials</u> - Basis - <u>1 kg (ton) acetic acid</u> <u>1 kg (ton) acetic anhydride</u> |                                |                                                 |
|------------------------------------------------------------------------------------------------------|--------------------------------|-------------------------------------------------|
| Acetaldehyde, kg (lbs)                                                                               | 1.10 (2,200)                   | 1.20 (2,400)                                    |
| Catalyst, g (lbs)                                                                                    | 3.30 (6.6) ( $\text{MnAc}_2$ ) | 1.0 (2) ( $\frac{\text{CuAc}}{\text{CoAc}_2}$ ) |
| Air, $\text{m}^3$ ( $\text{ft}^3$ )                                                                  | 0.251 (8,040)                  | variable                                        |
| Diluent (less recovery),<br>kg (lbs)                                                                 | ---                            | 1.65 (3,300)                                    |
| 3. <u>Operating Parameters</u>                                                                       |                                |                                                 |
| Temperature, °C (°F)                                                                                 | 55-80 (131-176)                | 50-70 (122-158)                                 |
| Pressure, kPa (atm)                                                                                  | 843-517 (4.77-5.10)            | 414 (4.09)                                      |
| Reaction time, hrs                                                                                   | 12                             | ---                                             |

4. Utilities - Basis - 4,536 (100  $\bar{M}$  kg/yr)

Water cooling,  $m^3/\text{min}$  - 25.3 (6,690)

Water makeup,  $m^3/\text{min}$  (gpm) - 1.25 (330)

Power, kW - 1,665

Steam, kg/hr (lbs/hr) -  $2.06 \times 10^4$  (45,420)

5. Waste Streams

Reaction section - off-gas scrubber vent

Methane - 1.8 g/kg (3.6 lbs/ton) acetic acid

Carbon monoxide - 3.3 g/kg (6.5 lbs/ton) acetic acid

Higher acids

Total waste flow -  $4.17 m^3/\text{kg}$  ( $10^3$  gallons/ton) product

Organics - >15 g/l

|                  | <u>Plant 1</u>        | <u>Plant 2</u>             |
|------------------|-----------------------|----------------------------|
| Flow             | $4.17 m^3/\text{kg}$  | $0.085 m^3/\text{kg}$      |
| COD              | 186 mg/l<br>0.78 g/kg | 306,100 mg/l<br>26.18 g/kg |
| BOD <sub>5</sub> | 84 mg/l<br>0.35 g/kg  | 64,000 mg/l<br>5.44 g/kg   |

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 128.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 158,183.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 408.

7. References (continued)

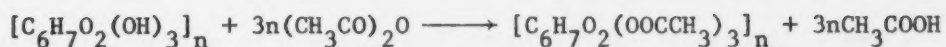
Faith, W. L. et al., Industrial Chemicals, 3rd Ed., Wiley & Sons  
New York, N.Y., 1965, p. 18-19.

Kent, J. A., Riegel's Handbook of Industrial Chemistry, 7th Ed., Van  
Nostrand Reinhold Co., New York, N.Y., 1974, p. 790.

Sittig, M., Acetic Acid and Anhydride, Noyes Development Corporation,  
Pearl River, N.Y., 1965, p. 29-31.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes  
Data Corp., Park Ridge, N.J., 1974, p. 54.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 8,9,16,17.

Cellulose Acetate

1. Function - Cellulose acetate is produced by the catalytic acetylation of high-quality cellulose, usually 98-99%  $\alpha$  - cellulose. This rather complicated batch process may be explained in terms of several subprocedures.

Pretreatment

The cellulose is first dried to a fixed optimum moisture content. A pretreating reagent, acetic acid, is then added to swell the cellulose and permit the acetylation reagent to diffuse into the fiber more rapidly. The time of pretreatment varies from 15 minutes to several hours.

Acetylation

The acetylation mixture consists of acetic anhydride, acetic acid (cellulose acetate solvent), and sulfuric acid catalyst. The amount of acetic anhydride used is slightly in excess of that required to react with the moisture in the cellulose and to form the triester.

For many applications, the cellulose acetate formed must be deesterified to some extent. This is accomplished by adjusting the water content to 5-10% and allowing hydrolysis to occur in the presence of sulfuric acid catalyst. When the desired ester content is reached, hydrolysis is arrested by neutralizing the sulfuric acid, usually with sodium acetate.

### Precipitation and Purification

The product is precipitated by dilution with water to some point just short of precipitation followed by mixing with an excess of aqueous acetic acid solution with vigorous agitation. The freshly precipitated product is purified by washing with water until all traces of acid are removed.

### Stablization

For the most part, product instability is due to the presence of sulfate ions in solution and trace amounts of sulfate esters. These are removed by adding magnesium ion and boiling in slightly acidified water. The stable product is then centrifuged and dried.

### Acetic Acid Recovery

All wash liquors containing an appreciable amount of acetic acid are combined to give an aqueous solution containing 18-20% acetic acid. Glacial acetic acid is obtained by concentrating this liquor.

## 2. Input Materials - Basis - 1 metric ton cellulose acetate

Cellulose - 700 kg (1543 lbs)

Acetic Acid - 3250 kg (7165 lbs)

Acetic Anhydride - 2000 kg (4409 lbs)

Sulfuric Acid (catalyst) - 100 kg (220 lbs)

Water

Sodium acetate or sodium bicarbonate



3. Operating Parameters

Temperature: Pretreatment - 40-50°C (104-122°F)

Acetylation - 5-45°C (41-113°F)

Hydrolysis - 25°C (77°F)

Drying - 95°C (203°F)

Pressure: slightly above atm.

Catalyst: 1% H<sub>2</sub>SO<sub>4</sub>

Reaction Time: 15-30 min.

4. Utilities

Not given

5. Waste Streams - The stills used to recover acetic acid and other solvents are major sources of waste water. The wastes contain considerable amounts of degraded cellulose and sulfuric acid. About 12-15 cubic meters of waste waters are generated per Mg (12-15 gal/1000 lb) of product with a solids loading of 200 g/m<sup>3</sup> depending upon the relationship of flake to fiber production.

Solvent handling operations are the principal potential sources of emissions to the air in the processing of cellulose acetate. Various solvents may be involved.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 127, 128.

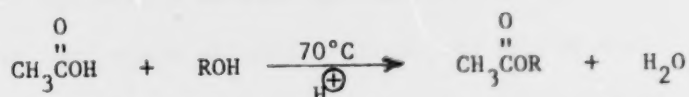
Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 4 (1964) p. 633-635.

U.S. Patent 3,040,027 (June 19, 1962).

Sittig, M., Organic Chemicals Process Encyclopedia - 1969, 2nd  
Edition, Noyes Development Corp., Park Ridge, N.J., 1969 , p. 156.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975 p. 239, 240.

Ethyl, Isopropyl Acetates

1. Function - Lower aliphatic acetates, such as ethyl and isopropyl acetate, are manufactured commercially by batch and continuous processes. The continuous process is favored for large volume production.

Batch Process - The esterification chamber (reactor) is a cylindrical tank or pot, heated by closed coil steam pipe. The acetic acid (8%), ethanol (95%), and catalyst (usually sulfuric acid) are charged in the ratio of 10:10:0.33. The mixture is heated by steam, and the vapors are fed to the base of a fractionating tower. The temperature at the top of the column is maintained at the boiling point of the ternary azeotrope of ethyl acetate (83%), ethanol (9%), and water (8%). The reflux from this tower is returned to the reactor. The vapors from the top of the column are sent to a reflux condenser, part of the condensate is returned to the column as reflux, and the rest is sent to storage.

The ultimate product of the batch process is the azeotrope ethyl acetate/ethanol/water. The azeotrope is satisfactory for many downstream commercial processes. However, others require pure ethyl acetate which is separated from the ternary azeotrope by the method used in the continuous process.

Continuous Process - The sulfuric acid/excess ethanol/acetic acid mixture is brought to equilibrium with agitation and heating. It

is then pumped to a receiving tank. The mixture is used in the reflux condenser as a heat exchange fluid. The heated mixture is then introduced near the top of a reaction column. The temperature at the top of the column is maintained at ethanol reflux temperature. Live steam is introduced at the base of the column. An additional feed of recovered alcohol is introduced simultaneously near the bottom of the column. Vapors from the reaction column containing approximately 10% water, are condensed and sent to a recovery column. The excess water and sulfuric acid are removed at the bottom of the reaction column. The acetic acid is consumed completely because there is always an excess of ethanol due to the constant removal of ethyl acetate and water.

The recovery column removes the excess alcohol from the ternary mixture and returns it to the reaction column. The ternary mixture, refluxing at the top of the recovery column, is condensed and recycled (to the bottom) until it approaches the composition of the constant-boiling ternary. The constant boiling ternary from the top of the recovery column is then sent to a mixing coil where water is added to form two layers. The layers are sent to a separator. The lower layer is sent back to the recovery column below the level of the feed plate, but above the base of the column.

The upper layer is sent to a second recovery column. The vapors are condensed and returned to the mixing coils. Ethyl acetate of 95-100% purity is taken from the bottom of the second recovery column. This product is then fractionated to obtain high-purity ethyl acetate and a small amount of constant boiling mixture which is returned to the first recovery column.

Ethyl acetate can be made by vapor phase esterification by reaction of ethylene with acetic acid, or by dehydrogenation of ethyl alcohol. These are not used commercially at present with the olefins below  $C_4$ , insofar as is known. Ethylacetate is also recovered as a by-product in polyvinyl alcohol production.

2. Input Material

95% ethanol  
8% acetic acid/92% water  
50-66° Be sulfuric acid  
Water  
Steam

3. Operating Parameters

Batch process - top plate of fractionating tower - 70°C (158°F)

est. reaction chamber temperature - 80°C (176°F)

top plate of recovery column - 78°C (172°F)

catalyst - 50-66° Be sulfuric acid

equipment - cylindrical tank, steam coil, perforated steam pipe, fractionating stills, ballcap column, pumps, condensers

Continuous process - top plate reaction column - 80°C (176°F)

bottom of recovery column - 100°C (212°F)

catalyst - 50-66° Be sulfuric acid

equipment - stirred reactors, steam-heated reaction column, reflux condensers, total condensers, mixing coils, separating tanks, receivers, cooling coils

4. Utilities - Not given.

5. Waste Streams

Batch Process - Dilute sulfuric acid stream from separation column sent to sewer and liquid leaks from pump seals. Possible vapor leaks from reactors, separation columns and condensers. No solid wastes.

Continuous Process - Dilute sulfuric acid from recovery column sent to sewer. Possible vapor leaks from reactors, reaction column, recovery columns, condensers, and fractionating columns. Liquid leaks from pump seals. No solid wastes.

6. EPA Source Classification Code - None.

7. References

Keyes, D. B., "Esterification Processes and Equipment", "Ind. Eng. Chem.", Vol. 24 (1932), p. 1096-1103.

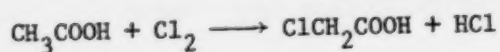
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 8 (1965), p. 313.

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 299.

U. S. Patent 2,787,636 (April 2, 1957).

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N. Y., 1975, p. 350, 351.



Chloroacetic Acid

1. Function - In the U.S., virtually all chloroacetic acid is produced by the direct chlorination of acetic acid. Catalysts such as sulfur and red phosphorus are used at temperatures of 85-120°C. The yield is about 95% based on acetic acid. Since HCl is a reaction by-product, glass-lined or specially designed corrosion-resistant equipment is used.

2. Input Materials

Basis - 1 metric ton chloroacetic acid

Acetic Acid - 688 kg (1517 lbs)

Chlorine - 813 kg (1792 lbs)

Red Phosphorus - 6.8 kg (15 lbs)

3. Operating Parameters

Temperature: 85-120°C (185-248°F)

Pressure: not given

Catalyst: Sulfur, red phosphorus

Chlorine Flow: 9-27 kg

4. Utilities

Not given

5. Waste Systems - Waste water streams from HCl absorbers and scrubbers may contain chlorine, hydrogen chloride, spent caustic, and chlorinated by-products. Vapors from reactors and the purification section may be expected to contain quantities of unreacted acetic acid,



chloroacetic acid, and reaction by-products, as well as some chlorine and HCl. However, no specific information was available.

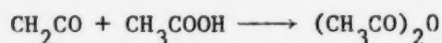
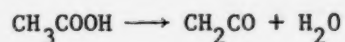
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y. Vol. 8 (1965), p. 816,417.

Faith, W. L., et al., Industrial Chemicals, John Wiley & Sons, Inc. New York, N.Y., 1965, p. 257,258.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 254,255.

Acetic Anhydride (from acetic acid and ketene)

1. Function - One method of producing acetic anhydride is the reaction of ketene and acetic acid. Ketene is first prepared by the catalytic cracking of acetic acid at 700° - 750°C. Triethyl phosphate is the usual catalyst. As reaction gases leave the converter, ammonia gas (1 kg/4.2 kg TEP) is injected into the stream to prevent reversion if the ketene is the product.

The reaction product passes from the pyrolysis tube to a cooling-separation system where the water from unreacted acetic acid are removed. The ketene is then reacted with acetic acid in two absorption towers at 30 - 40°C to produce acetic anhydride in yields approaching 90% based on acetic acid.

About half of the acetic anhydride produced in the U.S. is made by the Celanese Process. Acetic acid is cracked at somewhat lower temperatures (<700°C) to an equimolar mixture of ketene and acetic acid. After water is removed by flashing with benzene, the two reaction products combine to yield acetic anhydride.

2. Input Materials - Acetic acid - 1.25 kg/kg acetic anhydride 1350 mg/metric ton acetic anhydride

Ammonia gas - 16.8 kg/kg acetic anhydride

Benzene

Triethyl Phosphate - 0.25 kg/kg acetic anhydride

3. Operating Parameters - Ketene production

Temperature - 700°-750°C (1292-1382°F)

Pressure - 26.7 kPa (0.26 atm)

Catalyst - Triethyl Phosphate

Anhydride Production

Temperature - 30-40°C (86-104°F)

Pressure - Not given

4. Utilities - Not given

5. Waste Streams - Vent from gas scrubber system (air: This stream may contain methane, ethylene, and ketene, and they are normally fed to the burner to be used as fuel. Acetic anhydride column and acetic acid column: Heavy ends from these columns are generally incinerated. Gas scrubber system (water): Water streams may contain sodium hydroxide and sodium acetate. Some benzene expected in waste streams from the Celanese process.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals Part 1," "Chemical Engineering," January 21, 1974, p. 129.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

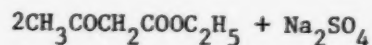
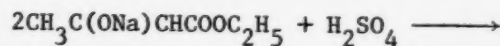
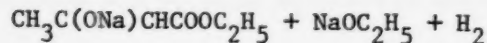
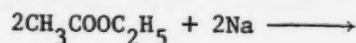
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 408.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 17,18.

Sodium Acetate (from acetic acid)



1. Function - Sodium acetate is made on a commercial scale by reacting alkali with acetic acid.
2. Input Materials  
Acetic acid  
Sodium hydroxide
3. Operating Parameters  
Not given
4. Utilities  
Not given
5. Waste Streams - Separator waste streams are probably the main pollutant sources in this process. Waste water streams may contain quantities of acetic acid and sodium hydroxide, and acetic acid may be present in the off-gas.
6. EPA Source Classification Code - None
7. References  
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 277.

Ethyl Acetoacetate (from ethyl acetate)

1. Function - Ethyl acetoacetate is most conveniently prepared by allowing high-purity ethyl acetate to react with metallic sodium or sodium ethoxide.

The sodium derivative is then neutralized with sulfuric acid. The yield is better than 90% after separation and vacuum distillation of the crude ester.

2. Input Material

Ethyl acetate - 1.50 kg/kg ethyl acetoacetate

Sodium

Sulfuric acid

3. Operating Parameters

Not given

4. Utilities

Not given

5. Waste Streams - Waste water from the separators may contain varying amounts of organic and inorganic sodium salts (sodium ethoxide, sodium sulfate, ethyl sodioacetate, etc.), ethyl acetate, ethyl

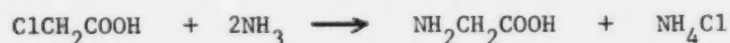
acetoacetate, and reaction by-products. Scrubbers may be used to remove excess sulfuric acid, and should also contribute to waste water pollution. Emissions from reactor, separation, and scrubber vents may contain any of the volatile reactants, products, and by-products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963) p. 158.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 499.

Glycine (ammonolysis of chloroacetic acid)

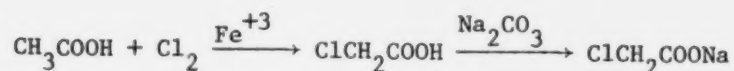
1. Function - Glycine is prepared on a commercial scale by adding an excess of aqueous ammonia to chloroacetic acid. Ammonium salts such as ammonium carbonate are often added to reduce the pH of the solution and inhibit conversion to the secondary and tertiary amine. Yields are generally good.
2. Input Materials - basic - 0.450 kg glycine  
Chloroacetic acid: 0.500 kg in 0.400 l H<sub>2</sub>O  
Aqueous ammonia (30%): 1.00 l  
Ammonia salts (or hexamethylene tetramine): 2.200 kg (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>  
H<sub>2</sub>O: 0.500 l
3. Operating Parameters  
Temperature: 40-90°C (104-194°F)  
Pressure: 101 kPa (1 atm)  
Reaction Time: 4-20 min.
4. Utilities - Not given.
5. Waste Streams - Wastewater from separators may contain ammonia, several ammonium salts, and traces of chloroacetic acid, glycine and other amine by-products. In ammonia recovery, some air emissions may occur, but no specific information was available.
6. EPA Source Classification Code - None.
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 2 (1963), p. 350.  
Cheronis, N. D., and K. H. Spitzmueller, J. Org. Chem., 6, 349 (1941).



U. S. Patent 3,215,736 (November 2, 1965).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition,  
Noyes Development Corp., Park Ridge, N. J., 1969, p. 350.

Sodium Chloroacetate (from Chloroacetic Acid)



1. Function - Acetic acid is chlorinated in the presence of iron,  $H_2SO_4$ , or  $PCl_3$  at 85-120°C to yield monochloroacetic acid in 95% yield. Even though the chlorine in chloroacetic acid is readily displaced from aqueous solutions of either itself or its alcoholic salts, the sodium chloroacetate is prepared by heating chloroacetic acid in  $Na_2CO_3$  to 50°C, then cooling to room temperature.
2. Input Materials  
  
Acetic acid  
  
Chlorine  
  
Iron,  $H_2SO_4$  or  $PCl_3$   
  
Sodium carbonate
3. Operating Parameters  
  
Temperature:      1st Step              85-120°C (185-248°F)  
                                 2nd Step              50°C      (122°F)  
  
Pressure:   not given  
  
Reaction time:   not given
4. Utilities  
  
Not given
5. Waste Streams - Excess chlorine, ferric chloride, and HCl should be in the waste streams from the first step and  $CO_2$ , and carbonic acid should be present from the second step.

6. EPA Source Classification Code

None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 415, 417.

Organic Synthesis, John Wiley and Sons, New York, N.Y., Coll. Vol. II  
(1943), p. 376.

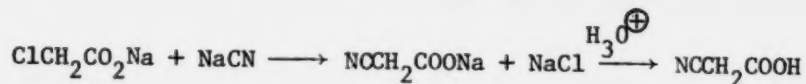
Ethyl Chloroacetate

1. Function - Ethyl chloroacetate is produced by the direct esterification of chloroacetic acid with absolute ethanol. Two moles of chloroacetic acid react with an excess of absolute ethanol (~ 3 moles) in the presence of 25g of concentrated sulfuric acid. The mixture is refluxed for six hours. The crude product is isolated and purified by conventional methods.
2. Input Materials  
Chloroacetic acid  
Ethanol
3. Operating Parameters  
Temperature: Reflux  
Pressure: 101 kPa (1 atm)  
Catalyst:  $\text{H}_2\text{SO}_4$
4. Utilities - Not given
5. Waste Streams - Traces of volatile reactants and products may be detected in air. Waste waters from washing crude product will contain sulfate salts, and traces of reactants and products. By-products may be present in waste waters from the purification by distillation.
6. EPA Source Classification Code - None

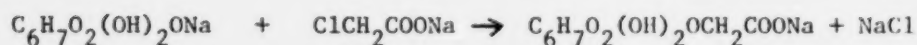
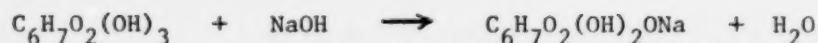
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 372.

Blatt, A. H., Organic Synthesis, Collective Vol. II, John Wiley &  
Sons, New York, N.Y., 1943, p. 263.

Cyanoacetic Acid

1. Function - Cyanoacetic acid is made by reacting the sodium salt of chloroacetic acid with sodium cyanide solution. Neutralization of the resulting mixture yields cyanoacetic acid.
2. Input Materials  
Chloroacetic acid - 1.24 kg/kg cyanoacetic acid  
Sodium cyanide
3. Operating Parameters  
Not given
4. Utilities  
Not given
5. Waste Streams - Information available was insufficient to identify pollutant sources in this process. However, waste water streams from various processing equipment may contain chloroacetic acid, sodium cyanide, cyanoacetic acid, and reaction by-products. Air vents may release any of the volatile reactants or products.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 417.  
Hahn, A. V., The Petrochemical Industry: Market and Economics, McGraw-Hill Book Co., New York, N. Y., 1970, p. 165.

Sodium Carboxymethyl Cellulose

1. Function - Sodium carboxymethyl cellulose is produced by a two-step process, involving the addition of sodium hydroxide and sodium chloroacetate to cellulose.

Only 13-50% of the available hydroxyl group react to yield alkali cellulose, the properties of the final product being quite dependent on this fraction.

The alkali cellulose formed is then combined with sodium chloroacetate at 35-45°C to yield the final product.

After drying, the crude product contains considerable amounts of sodium chloride and other diluents, such as sodium glycolate.

If necessary, these impurities may be removed by washing with methanol or ethanol.

2. Input Materials

Cellulose 1 part  
Sodium hydroxide - 10 parts  
Sodium chloroacetate - 1.5 parts  
Methanol or ethanol

3. Operating Parameters

Temperature: 35-45°C (95-113°F)  
Pressure: 101 kPa (1 atm)

4. Utilities - Not given.



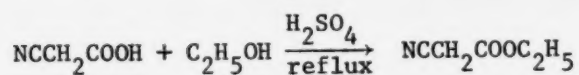
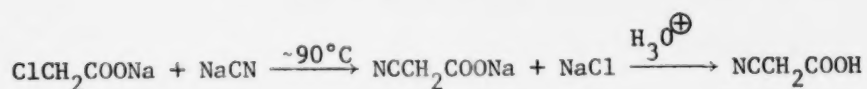
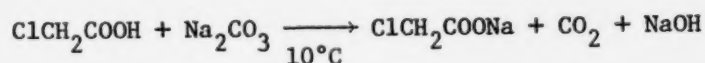
5. Waste Streams - Wastewater streams from washing operations may contain unreacted sodium hydroxide, alkali cellulose, sodium chloroacetate, or chloroacetic acid, and reaction by-products, such as sodium glycolate. Methanol or ethanol may also be present.
6. EPA Source Classification Code-None.
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8", July 22, 1974, p. 112.

U. S. Patent 3,322,798 (May 30, 1976).

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 4 (1964), p. 644, 645.

Sittig, M., Organic Chemical Process Encyclopedia - 1960, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 601.

Ethyl Cyanoacetate

1. Function - Ethyl cyanoacetate is manufactured by esterification of cyanoacetic acid with ethyl alcohol. The cyanoacetic acid is formed via the reaction of sodium chloroacetate with sodium cyanide.

The crude ester (washed, dried) is purified by distillation under reduced pressure.

2. Input Materials

Chloroacetic acid

Water

$\text{Na}_2\text{CO}_3$  (neutralize chloroacetic acid)

NaCN

HCl (to liberate cyanoacetic acid)

$\text{C}_2\text{H}_5\text{OH}$

3. Operating Parameters

Temperature: Neutralization  $\text{ClCH}_2\text{COOH}$  -  $10^\circ\text{C}$  ( $50^\circ\text{F}$ )

Formation - sodium cyanoacetate -  $-90^\circ\text{C}$  ( $194^\circ\text{F}$ )

Esterification - reflux temperature

4. Utilities - Not given
5. Waste Streams - Excess NaCN reacts with HCl to give HCN, which is vented to the air. Waste waters may contain salts, dilute acids, traces of alcohol, and of ethyl cyanoacetate.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 853-854.

Gilman, H., Organic Synthesis, 2nd Edition, 5th Printing, John Wiley and Sons, New York, N.Y., Collective Vol. I, 1948, pp. 254-256.

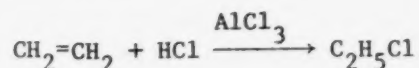
Ethylene Dibromide

1. Function - Ethylene dibromide is produced by the reaction of ethylene and bromine. The reaction takes place in earthenware or glass vessels, the ethylene being passed into the bromine. After any free acid is neutralized, the product is purified by fractionation. The yield is approximately 90% of the theoretical.
2. Input Materials - Per kg product (2.2 lbs)  
Ethylene - 1.166 kg (2.57 lbs)  
Bromine - 0.933 kg (2.06 lbs)
3. Operating Parameters  
Temperature 10-100°C (50-212°F)  
Pressure 101 kPa (1 atm)  
Reaction Time 16 hrs (batch)  
2 hrs (continuous)
4. Utilities  
Not given
5. Waste Streams - No information was available, but waste streams from distillation columns and other processing equipment may contain traces of reactants, reaction products (ethylene dibromide and by-products), and free acid neutralization products.
6. EPA Source Classification Code - None
7. References  
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 5," "Chemical Engineering," April 29, 1974, p. 146.

7. References (continued)

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 771.

Sittig, M., Chemicals from Ethylene, Noyes Development Corporation,  
Pearl River, N.Y., 1965 , p. 36, 37.

Ethyl Chloride (from ethylene)

1. Function - Eighty-eight percent of the ethyl chloride produced in the U.S. is made by the liquid-phase reaction of dilute ethylene and hydrogen chloride.

The reaction is carried out at normal temperature and pressure in an 0.2% solution of aluminum chloride in ethyl chloride. The yield is approximately 90% of the theoretical.

2. Input Materials

Basis - 1 kg ethyl chloride

Ethylene - 0.488 kg

Hydrogen chloride - 0.625 kg

Catalyst - 5 g

3. Operating Parameters

Temperature: 35-40°C (95-104°F)

Pressure: 372 kPa (3.67 atm)

Catalyst: 0.2%  $\text{AlCl}_3$  solution

4. Utilities

Not given

5. Waste Streams - Emissions from air vents and wastewater streams may include ethylene, hydrogen chloride gas, hydrochloric acid,  $\text{CH}_4$ ,  $\text{CO}_2$ , ethyl chloride, and trace amounts of catalyst.

6. EPA Source Classification Code - None

7. References

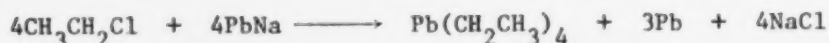
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 5," "Chemical Engineering," April 29, 1974, p. 144, 145.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 5 (1964), p. 144.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 133, 134.

Sittig, M., Organic Chemical Processes, The Noyes Press, Inc., Pearl River, N.Y., 1962, p. 55.



Tetraethyl Lead (via lead amalgam)

1. Function - The major reaction for the production of tetraethyl lead involves the addition of lead amalgam to ethyl chloride at 65-75°C and 345-414 kPa (50-60 psig). The lead amalgam used is about 90% lead and 10% sodium.

The yield based on sodium feed exceeds 90%. Some sodium is lost to side reactions, which form hydrocarbons. The tetraethyl lead formed is steam distilled and purified. The lead sludge is reprocessed.

2. Input Materials

Ethyl chloride

Lead amalgam

90% lead - 0.75 kg/kg tetraethyl lead

10% sodium - 0.32 kg/kg tetraethyl lead

3. Operating Parameters

Temperature - 65-75°C (149-167°F)

Pressure - 345-414 kPa (3.40-4.09 atm)

4. Utilities - Not given

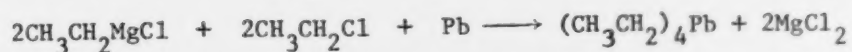
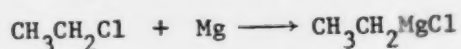
5. Waste Streams - Hydrocarbons formed by combination and disproportionation of ethyl radicals are normally vented during reaction period. The effluents from washings may contain small amounts of oxidizing agents, reaction products and sodium chloride from the washings of the lead sludge.
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 114.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 290-293.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975 , p. 502-508.

Tetraethyl Lead (via electrolysis)

1. Function - The newer electrolysis process is used mainly to produce tetramethyl lead but is suitable for the manufacture of other lead alkyls. The process consists of two major steps: 1) Synthesis of a Grignard reagent from magnesium and ethyl chloride in anhydrous mixed ethers such as THF and diethylene glycol; and 2) Electrolysis of the solution of the Grignard reagent where the ethyl radicals migrate to an anode of lead pellets and combine to form tetraethyl lead. Magnesium migrates to the cathode (steel wall of the cell) and reacts with excess ethyl chloride to give magnesium chloride.
2. Input Materials  
Ethyl chloride  
Magnesium  
Lead  
Tetrahydrofuran  
Diethylene glycol dibutyl ether
3. Operating Parameters  
For Grignard reagent formation: Temperature - 350°C (662°F)  
Pressure - 69-138 kPa (0.68-1.36 atm)
4. Utilities - Not given

5. Waste Streams - No information available. Possible emissions from recycling and purification of solvents.

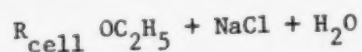
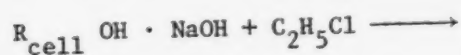
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 114, 115.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 290-293.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 502-508.

Ethyl Cellulose

1. Function - On a commercial scale, ethyl cellulose is made by the liquid-phase reaction of alkali cellulose and ethyl chloride. The alkali cellulose is prepared by mixing a 50% aqueous sodium hydroxide solution with cellulose. Since high sodium hydroxide concentration favors the main reaction, the concentration is kept as high as possible.

After several hours, the alkali cellulose is added to a nickel-lined pressure vessel along with ethyl chloride and a diluent such as benzene or toluene. The conversion to ethyl cellulose requires 6-12 hours at 90-150°C.

The exact substitution may be controlled by the sodium hydroxide concentration, the ethyl chloride input, or the reaction temperature.

A number of side reactions occur during this conversion, the principal ones being the hydrolysis of ethyl chloride to ethanol and the subsequent formation of ethyl ether.



The extent of these side reactions is reduced by increasing the sodium hydroxide concentration, decreasing the water content of the reaction mixture, and the presence of benzene or toluene. However, the ethyl chloride efficiency is still rather low.

At the end of the etherification, the pressure is released slowly, allowing the volatile ethyl chloride, ether, alcohol, and any diluent to distill off. The spent sodium hydroxide is drained off for recovery, and the product is purified by washing in stainless steel equipment. The by-products, ethanol and ethyl ether may be reconverted to ethyl chloride by heating with HCl in the presence of  $\text{ZnCl}_2$  catalyst.

2. Input Materials - Basis - 56 kg ethyl cellulose

Cellulose - 45 kg (99.2 lbs)

50% NaOH solution - 628 kg (1384.5 lbs)

Ethyl chloride - 220 kg (485.0 lbs)

Benzene or toluene

Hydrogen chloride

3. Operating Parameters

Temperature: Alkali cellulose 35-40°C (95-104°F)

Ethylation 90-150°C (194-302°F)

Pressure: 0.2-2.2 MPa (2-22 atm)

Catalyst: By-product conversion -  $\text{ZnCl}_2$

4. Utilities

Not given

5. Waste Streams

Purification (air)

Ethyl chloride, ethanol, ethyl ether, and benzene or toluene may be present in air emissions from distillation operations.

Purification (water)

Waste water from washing operations may be expected to contain quantities of caustic soda, ethyl cellulose, and all of the pollutants previously mentioned. Degraded cellulose may also be present along with sodium chloride.

By-product conversion

Ethyl chloride, ether, alcohol, spent catalyst, and tars may be present in the waste streams from this process step.

Benzene/Toluene recovery

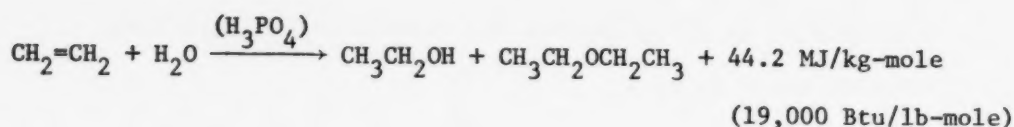
Benzene or toluene may be present in the extract water, and in air emissions along with purification solvents.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 4 (1964), p. 640, 641.



Ethanol (hydration of ethylene) and Diethyl Ether

1. Function - Synthetic ethanol has been manufactured from ethylene by two processes, i.e., the direct hydration process and the absorption process. The last large absorption process plant shut down in late 1974, so that essentially all of the synthetic ethanol is now being manufactured by the direct hydration process.

The hydration process involves catalytic addition of water to ethylene. Phosphoric acid, impregnated on an inert support such as Celite diatomite is commonly used. High pressures and temperatures are required for this exothermic process.

Fresh ethylene feed (98+%) plus recycle ethylene are compressed and mixed with 0.5-1.0 mole water per mole of ethylene. The gaseous mixture is preheated and then fed to a reactor. The vapor leaving the reactor is slightly hotter than the feed because of the exothermic reaction. The reactor effluent is cooled and treated with a small amount of caustic soda. The condensed ethanol/water mixture is sent to a separator where the aqueous ethanol is separated from unreacted gases. The gases are scrubbed with water to remove traces of ethanol, and are returned to the reactor as recycle ethylene. A small purge stream is removed to prevent buildup of impurities in the recycle ethylene.

The aqueous ethanol solution from the scrubbing step is combined with the liquid product from the separator. The mixture is concentrated to 190° proof ethanol (95 vol %) by conventional distillation techniques. For anhydrous ethanol (absolute ethanol; 200° proof ethanol), the 95 vol % ethanol is fed to a dehydrator where water is removed as an azeotrope. Benzene is commonly used.

Relatively small amounts of by-products are produced in this reaction. They are: ether, aldehydes, higher hydrocarbons, higher alcohols, and ketones. Ether is the principle by-product.

The conversion of ethylene to ethanol is limited to low values per pass by the thermodynamic equilibrium at practical operating conditions. Therefore, a large recycle volume of unconverted ethylene is required. The temperature, pressure, water to ethylene ratio, and ethylene purity are important variables, and must be closely controlled for maximum efficiency.

Ethanol is also produced by fermentation. It can be synthesized by an oxo-related process which involves the reaction of methanol with carbon monoxide and hydrogen at high temperature and pressure over a cobalt catalyst. Ethanol is also produced in minor quantities during the oxidation of n-butene.

## 2. Input Materials

Ethylene - 747 kg/metric ton (1495 lb/short ton) product

Water - 4,682 kg/metric ton (9,365 lb/short ton) product

Hydrogen - 0.035 kg/metric ton (0.07 lb/short ton) product

Sodium hydroxide - 2.5 kg/metric ton (5 lb/short ton) product

3. Operating Parameters - The conditions recommended for highest efficiency are:

Reactor temperature - 299°C (570°F)

Reactor pressure - 6.7-7.0 MPa (661-69.1 atm)

Reactor feed ethylene concentration, water free basis - 85%

Ethylene makeup concentration - 97%

Water to ethylene ratio in feed - 0.6

Space velocity - 26.5-30 (volume of gas at 15.6°C (60°F) and  
101 kPa (1 atm)/min - vol. of catalyst)

Ethylene conversion per pass - 4.2-5%

Water conversion - 7.0%

Overall yield, ethylene to ethanol - >97%

4. Utilities - Basis - 84,900 metric tons (93,600 short tons)/yr

Water - 1.8 m<sup>3</sup>/s (28,900 gpm)

Steam - 97,800 kg (216,000 lb)/hr

Fuel gas - 11 MW (38 MM Btu)/hr (excluding 1.2 dam (45,000 scf)/hr  
gas bleed)

Electricity - 1.747 kW

Nitrogen - 6.2 m<sup>3</sup> (2,200 scf)/hr

5. Waste Streams

Water - The major source results from separation of product from process bottoms and may amount to 15-30 kg (33-66 lb) of COD/metric ton of product.

Air - 1.1 kg (2.5 lb) ethanol/metric ton of product plus traces of acetaldehyde, ether, ethylene, and ethylene impurities from the purification section. Leaks in compressor seals, as well as in

the gas handling system, are also a possible source of air pollution. Also present are olefin polymers, acetaldehyde, and diethyl ether.

6. EPA Source Classification Code - None

7. References

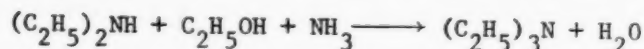
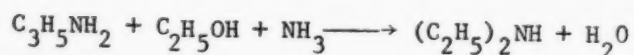
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 434, 435, 436.

Considine, D. M., Ed., Chemical and Process Technology Encyclopedia, McGraw-Hill Book Co., New York, N.Y., 1974 , p. 423-427.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollutational Problems Associated with Petrochemical Wastes," Prepared for FWPCA, Contract 14-12-461, Robert S. Kerr Water Research Center, Ada, Oklahoma, February 1970.

U.S. Patent 2,773,910 (December 11, 1956).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969 , p. 297.

Mono-, di-, triethylamine (from ethanol and ammonia)

1. Function - Ethylamine, diethylamine, and triethylamine are all produced by the reaction of ethyl alcohol and ammonia under heat and pressure. The reaction is run in the vapor phase.

Although mixtures of amines are always produced, the reaction products can be controlled to a certain extent. A large excess of ammonia favors ethylamine production. If this product is recycled, more di- and triethylamines will be produced. These amines used to be synthesized from ethyl chloride until they became large volume chemicals. Then the starting material was switched to the cheaper ethyl alcohol.

The alkylation of ammonia by alcohols has been accomplished in the presence of hydrogen and a hydrogenation catalyst consisting of a mixture of nickel and copper deposited on alumina activated with boric acid. Thus two moles of ethanol, one mole of ammonia, and three moles of hydrogen were passed over the catalyst at 220°C to yield a product consisting of ethyl-, diethyl-, and triethylamines in the ratio of 1:5:3. The conversion of ethanol amounted to 52 percent.

2. Input Materials - per metric ton (2,205 lbs) product

|                                             | <u>MEA</u>  | <u>DEA</u>  | <u>TEA</u>  |
|---------------------------------------------|-------------|-------------|-------------|
| Ethyl alcohol, kg (lbs)                     | 1122 (2474) | 1384 (3051) | 1500 (3307) |
| Ammonia - excess, kg (lbs)                  | 402 (886)   | 248 (547)   | 179 (395)   |
| Catalyst, kg (lbs)                          | 12 (2.6)    | 1.2 (2.6)   | 1.2 (2.6)   |
| Hydrogen, m <sup>3</sup> (ft <sup>3</sup> ) | 14.2 (500)  | 14.2 (500)  | 14.2 (500)  |

3. Operating Parameters

Temperature - 400°C (752°F)

Pressure - 10.13 MPa (100 atm)

Reaction time - 2-3 hrs.

4. Utilities - per 45.5 kg (100 lbs) product

Steam @ 1.04 MPa (10.3 atm) - 680.4 kg

Cooling water (10°C rise) - 26.5 m<sup>3</sup> (7,000 gal.)

Electricity, MJ-28.8 (8 kWh)

5. Waste Streams - Excess ammonia, ethyl alcohol, and all three amines may be present in the off-gas from the ammonia stripper. Organic and inorganic ammonium salts, as well as the pollutants mentioned, should be expected in the wastewater stream. If the liquid phase process is used, the alcoholic solvent may be present in both cases. Volatiles may also be emitted from other processing steps.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition

Interscience Publishers, New York, N.Y., Vol. 8 (1963), p. 455.



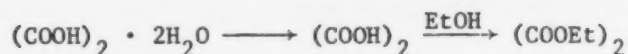
7. References

Astle, M. J., Industrial Organic Nitrogen Compounds, Rheinhold Publishing Corp., New York, N.Y., 1961, p. 7, 8.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 511, 512.

"1973 Petrochemical Handbook", "Hydrocarbon Processing," November, 1973, p. 115.



Ethyl Oxalate (direct esterification)

1. Function - Ethyl oxalate is manufactured by the conventional esterification of oxalic acid. Oxalic acid is sufficiently acidic to serve as its own esterification catalyst, but mineral acids and ion exchange resins are sometimes used.

Since commercial oxalic acid is generally the dihydrate, the process may be more economical if the acid is dehydrated and esterified in a single operation. If the dihydrate is reacted, it is necessary to remove twice the usual proportion of water to complete the reaction.

Low-boiling solvents capable of forming azeotropes with water are preferred to remove the water of crystallization. After dehydration, esterification is carried out in the same reactor using the same solvent to remove water produced during the reaction. The last traces of water are most difficult to remove and this is accomplished by a special step in the rectification. Yields of 90 - 92% are achieved.

2. Input Materials

Oxalic acid dihydrate - 0.95 kg/kg ethyl oxalate

Ethanol - 0.69 kg/kg ethyl oxalate

Low-boiling solvent

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst: Mineral acids

Ion exchange resins

4. Utilities

Not given

5. Waste Streams - Although no information was available, wastewater streams from the separator may be expected to contain quantities of solvent, unreacted ethanol and oxalic acid, ethyl oxalate, and reaction intermediates and by-products. Some solvent and ethanol are probably released through air vents in the separator and other processing equipment.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 14 (1967), p. 370.

Ethyl Acrylate (direct esterification)

1. Function - Ethyl acrylate is usually made in a modification of an acrylic acid process by adding ethanol to the reactant mix. The processes based on propylene for acrylic acid appear to be growing fastest because of propylene's low cost; acetylene and ethylene are being phased out as raw materials. The esterification of acrylic acid is accomplished in the presence of sulfuric acid, Dowex<sup>®</sup> 50 ion exchange resin, or silica gel catalyst.

Hydroquinone or other polymerization inhibitors are added during distillation.

2. Input Materials

Acrylic acid - 737.5 kg/Mg product

Ethanol - 476.5 kg/Mg product

3. Operating parameters

Temperature - not given

Pressure - not given

Catalyst -  $\text{H}_2\text{SO}_4$ , Dowex<sup>®</sup> 50 ion exchange resin or silica gel.

4. Utilities\* - basis: 0.430 kg/sec (0.95 lb/sec) capacity

Steam - 364 kg/sec (8 lb/sec)

Power - 169 kW capacity

Cooling water - 151 dm<sup>3</sup>/sec (40 gal/sec)

Makeup water - 5.11 dm<sup>3</sup>/sec (1.35 gal/sec)

Refrigeration - 15.4 Mg

\* Data from plant using Dowex<sup>®</sup> 50 ion exchange resin.

5. Waste Streams \*

Heavy ends from the ester purification column:

Polymers - 11.9 kg/Mg (1b/1000 lb) product

Hydroquinone - 13.75 kg/Mg (1b/1000 lb) product

Overhead from the ester purification section (air):

Ethanol - 2.65 kg/Mg (1b/1000 lb) product

Ethyl acrylate - 1.6 kg/Mg (1b/1000 lb) product

Ethyl acetate - 5.25 kg/Mg (1b/1000 lb) product

Sodium carbonate - 0.26 kg/Mg (1b/1000 lb) product

6. EPA source classification code - None

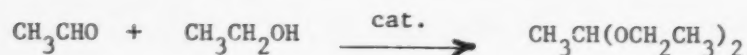
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 4," "Chemical Engineering," April 15, 1974, p. 90.

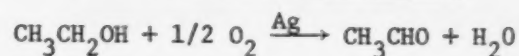
Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 297, 298.

\* Data from plant using Dowex<sup>®</sup> 50 ion exchange resin.

Acetal (from acetaldehyde and ethanol)

1. Function - Acetal (specifically, diethyl acetal) is formed by the condensation reaction of acetaldehyde and ethanol. Catalysts used in this process may be acids (hydrochloric, p-toluenesulfonic) or salts (calcium chloride, ammonium chloride). In some cases, azeotropic distillation is employed to remove the water of reaction and improve the yield.
2. Input Materials  
Acetaldehyde  
Ethanol
3. Operating Parameters  
Temperature: Not given  
Pressure: Not given  
Catalyst: acids or salts
4. Utilities - Not given.
5. Waste Streams - Wastewater streams from the purification section may contain acetaldehyde, ethanol, acetal, and either acid or salt catalyst. Volatile reactants and products may be emitted through air vents in the reactor, separator, and other process equipment.
6. EPA Source Classification Code - None.
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 81, 108.

Acetaldehyde (from ethanol)

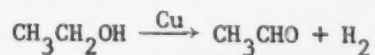
1. Function - As of 1974, only 15% of the United States acetaldehyde capacity was based on ethanol. There are two processes for conversion of ethanol to acetaldehyde, i.e., oxidative dehydrogenation and catalytic dehydrogenation.

Oxidative dehydrogenation

The vapor phase reaction is carried out over solid silver gauze catalyst at 538°C (1000°F). Aqueous ethanol, steam, and air are fed to the oxidizer (reactor). The reactor effluent is condensed and is passed to a phase separator which also serves as a scrubber (refrigerated water). The off gases are vented from the system and the wash is combined with the liquid stream. The combined liquid stream is sent to a flash column where it is separated into acetaldehyde product, alcohol for recycle, and waste water. The acetaldehyde product from the flash column is sent to an ethanol recovery still where acetaldehyde product is taken from the top and the bottoms (primarily ethanol) are recycled to the reactor.

Catalytic dehydrogenation

The primary reaction is:



The vapor phase reaction is carried out over a solid copper catalyst promoted by cobalt or chromium on an asbestos support at 260°C (500°F). The recovery and isolation systems are almost identical to those in oxidative dehydrogenation. The yields in both processes range from 85 to 95%.

## 2. Input Materials

Oxidative dehydrogenation: air

ethanol

steam

water

Catalytic dehydrogenation: ethanol - 1150 kg/metric ton (2,535 lbs/ton)  
acetaldehyde

## 3. Operating Parameters

Oxidative dehydrogenation: temperature - 538°C (1000°F)

pressure - 410 kPa (4.05 atm)

flow rate - not given

equipment - multitubular reactor,  
phase separator, flash  
column, still

catalyst - solid silver gauze

Catalytic dehydrogenation: temperature - 260°C (500°F)

pressure - not given

flow rate - not given

equipment - see oxidative  
dehydrogenation

catalyst - solid copper catalyst  
promoted by cobalt or  
chromium on an asbestos  
support

## 4. Utilities - The water usages of two plants are:

|         | <u>Process water</u> | <u>Cooling water</u> |
|---------|----------------------|----------------------|
| Plant 1 | 5.9 kg/kg product    | 47.2 kg/kg product   |
| Plant 2 | 0.45 kg/kg product   | 45.4 kg/kg product   |



## 5. Waste Streams

Air - Off gases from the phase separator; it has been estimated that 12.2 Mg (27 MM lb) of CO is emitted annually from this industry.

Water - The only wastewater stream generated is either from the acetaldehyde flash column or ethanol recovery still. It contains liquid products such as acetaldehyde, ethanol, and ethyl acetate. Data on two plants (one using each of the two processes) was as follows:

|      | <u>Plant 1</u>                                         | <u>Plant 2</u>                                           |
|------|--------------------------------------------------------|----------------------------------------------------------|
| Flow | 6.0 m <sup>3</sup> /<br>454 kg<br>product              | 529 dm <sup>3</sup> /<br>454 kg<br>product               |
| COD  | 0.186 kg/m <sup>3</sup> (186<br>mg/l) 1.1 kg/454<br>kg | ----                                                     |
| BOD  | 0.084 kg/m <sup>3</sup> (84 mg/<br>l) 0.50 kg/454 kg   | ----                                                     |
| TOC  | ---                                                    | 14.4 kg/m <sup>3</sup> (14,400<br>mg/l) 7.6 kg/454<br>kg |

6. EPA Source Classification Code - None

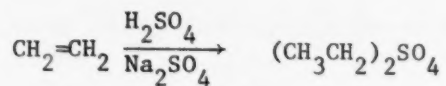
## 7. References

Austin, G. T., "Industrially Significant Organic Chemicals -  
Part 1," "Chemical Engineering," January 21, 1974, p. 128.

Waddams, A. L., Chemicals from Petroleum, 3rd Ed., John Murray Ltd., London, Eng., 1973, p. 75, 76.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, N.J., 1974, p. 47-50.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 3.

Diethyl Sulfate (from ethylene)

1. Function - The most economical route to diethyl sulfate involves the action of 96% sulfuric acid on ethylene at 60°C. The resulting mixture of 43% diethyl sulfate, 45% ethyl hydrogen sulfate, and 12% sulfuric acid is heated with anhydrous sodium sulfate under vacuum and diethyl sulfate is obtained in 86% yield.
2. Input Materials  
Ethylene  
Sulfuric acid  
Sodium sulfate
3. Operating Parameters  
Temperature - 60°C (140°F)
4. Utilities - not given
5. Waste Streams - No process information was available. If excess acid and the water of reaction are separated prior to distillation, wastewater streams may contain sulfuric acid, diethyl sulfate, and monoethyl sulfate, a reaction intermediate. Miscellaneous air emissions may contain the same pollutants.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 492.

7. References (continued)

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4  
(1972), p. 278, 504.

Propanoic Acid (from ethylene)

1. Function - One competitive process for the production of propionic acid involves the reaction of ethylene, carbon monoxide, and water in the presence of a  $\text{NiCO}_3/\text{H}_3\text{BO}_3$  catalyst. The liquid phase reaction is run in a stainless steel autoclave. The product (40% propionic acid in water) may be purified by rectification. The autoclave is charged with 300 g of 17.2 weight percent propionic acid, 0.823 g Ni as  $\text{NiCO}_3$ , 3.15 g  $\text{H}_3\text{BO}_3$ , 100 g  $\text{C}_2\text{H}_4$ , and 50 g CO. The temperature is raised to 153°C at 13.88 MPa (137 atm) at which time the temperature and pressure jump to 288°C and 23.3 MPa (230 atm). The reaction is cooled after 30 min and filtered to yield a 40% solution of propionic acid which also contains 0.70 g Ni. In a continuous process, the normal rate of 292 g acid/g Ni goes to 1320 g acid/g Ni by using a stoichiometric excess of  $\text{H}_3\text{BO}_3$  with respect to the nickel ion concentration.

Propionic acid has also been prepared from ethanol and carbon monoxide.

2. Input Materials

Ethylene - 100 g (0.22 lbs)

Carbon monoxide - 50 g (0.11 lbs)

Propionic acid (17.2 wgt %) - 300 g (0.66 lbs)

$\text{H}_3\text{BO}_3$  - 3.15 g (0.0069 lbs)

Ni (as  $\text{NiCO}_3$ ) - 0.823 g (0.0018 lbs)

3. Operating Parameters

Temperature: 1st stage 153°C (307° F)  
2nd stage 288°C (550° F)  
Pressure: 1st stage 13.88 MPa (137 atm)  
2nd stage 23.3 MPa (230 atm)  
Catalyst:  $\text{NiCO}_3/\text{H}_3\text{BO}_3$

4. Utilities - None given.

5. Waste Streams - Propionic acid will be in the aqueous waste streams along with nickel salts and boric acid. Excess CO and ethylene may be present in air emissions.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 16 (1968), p. 555.

Sittig, M., Oxo Process and Products, Noyes Development Corp., Park Ridge, N.J., 1966, p. 105, 106.

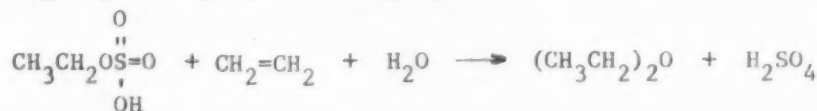
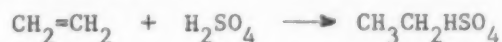
U.S. Patent 3,151,155 (September 29, 1964).

Diethyl Ether (from ethanol)

1. Function - There have been several processes for the manufacture of ethyl ether, i.e., dehydration of ethanol with sulfuric acid;



the addition of sulfuric acid to ethylene (indirect hydration or absorption process);



the direct hydration of ethylene.



The dehydration process was designed primarily for the production of ethyl ether, whereas ethyl ether is the principal by-product in the direct or indirect hydration process. At present, most of the ethyl ether produced is manufactured by the vapor phase catalytic dehydration of ethanol.

2. Input Materials

Ethanol

Catalyst (tungsten oxide/ $\text{Al}_2\text{O}_3$ )



3. Operating Parameters

Temperature: 120-375°C (248-707°F)

Pressure: 0.103-10.3 MPa (1.02-102.1 atm)

Contact Time: 30 min

4. Utilities - Not given

5. Waste Streams - Unreacted ethanol and some catalyst should be present in the waste streams.

6. EPA Source Classification Code - None

7. References

Faith, W. L., et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N. Y., 1965, p. 335-338.

U. S. Patent 2,805,260 (September 3, 1957).

Chemical Technology, Barnes and Noble Books, New York, N. Y., Vol. 4 (1972), p. 333.

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 326.

Acetamide (ammonolysis of ethyl acetate)

1. Function - Acetamide is currently produced by the interaction of ethyl acetate and aqueous ammonia. Ethanol is a by-product of this reaction. The crude product is purified by crystallization.

In the past, acetamide has been made from the acid chloride, acetic anhydride, ammonium acetate, acetic acid, and ketene, among other materials. Recently, the ethyl acetate route has proven most economical.

2. Input Materials

Ethyl acetate

Aqueous ammonia

3. Operating Parameters

Not given

4. Utilities

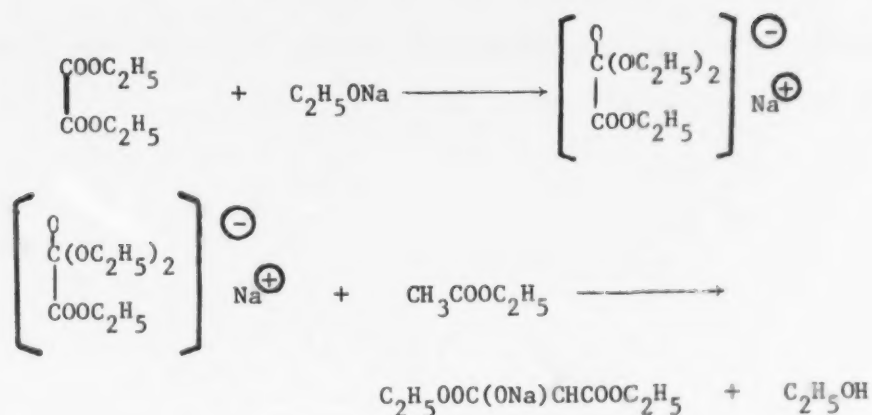
Not given

5. Waste Streams - Waste water and air emissions from the ammonia stripper may contain any of the reactants or products. Some additional air emissions may result from recycling operations.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 144.

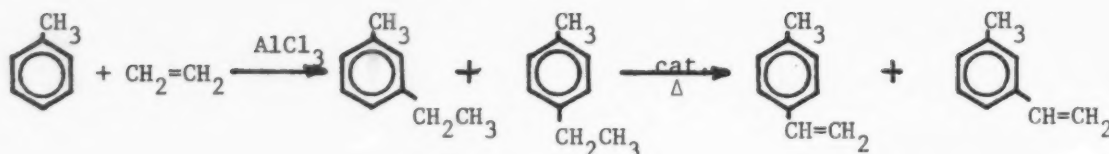
Ethyl Sodium Oxalacetate

1. Function - Ethyl sodium oxalacetate is made by the reaction of pure ethyl acetate with the adduct formed by the reaction of diethyl oxalate and sodium alcoholate.
2. Input Materials
  - Ethyl acetate
  - Ethyl oxalate
  - Sodium
  - Absolute alcohol ether
3. Operating Parameters
  - Addition of reagents - Ice-water bath
4. Utilities - Not given
5. Waste Streams - Wastewater streams may contain organic sodium salts and any of the reactants or products.

6. EPA Source Classification Code - None

7. References

Houben-Weyl, Methoden Der Organischen Chemie, Vierte Auflage, Georg  
Thieme Verlag, Stuttgart, Bd. 8 (1952), p. 582.

Vinyltoluenes

1. Function - Vinyltoluenes are produced commercially by alkylation of toluene with ethylene followed by dehydrogenation of the m-, and p-ethyltoluenes. Toluene is alkylated with ethylene in a reactor similar to that used for ethylbenzene manufacture. Reaction temperature is kept below 100°C.

The crude alkylation product consists of a mixture of o-, m-, and p-ethyltoluene, polyethyltoluenes, benzene, ethylbenzene, xylenes, "lights", and tars.

The crude product is cooled, washed with alkali, and purified by a series of fractional distillations. Toluene, polyethyltoluenes, and the unusable o-ethyl toluene are recycled to the alkylator while other by-products are reclaimed by other means. The m- and p-ethyltoluene mixture is then heated to 450-500°C, mixed with two to three times its weight of super-heated steam, and passed over a dehydrogenation catalyst.

The separation of the m- and p- vinyltoluenes from the crude hydrogenation mixture is accomplished by a series of vacuum distillations.

2. Input Materials

Ethylene

Toluene

$\text{AlCl}_3$

3. Operating Parameters

Ethylation

Temperature: < 100°C (212°F)

Pressure: Not given

Dehydrogenation

Temperature: 450-500°C (842-932°F)

Pressure: Not given

Catalyst: various dehydrogenation catalysts

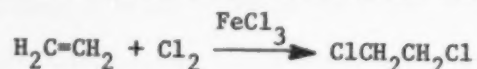
4. Utilities - Not given

5. Waste Streams - Ethylation: Effluents likely contain solutions of aluminum salts, HCl, sodium hydroxide, sodium chloride, and traces of the various aromatic reactants and by-products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 77-80.

Ethylene Dichloride (1,2-dichloroethane) (direct chlorination)

1. Function - There are two commercial processes for making ethylene dichloride (EC) from ethylene: the oxychlorination process and the direct addition process. Over 95% of the EC produced in the United States in 1974 was made by the "balanced process," which is a balanced combination of the two processes. Approximately 2.4% of the EC was made exclusively by oxychlorination, while 2.6% was made exclusively by the direct addition of chlorine to ethylene. The oxychlorination process is described in Process No. 131.

As of 1975 EC accounts for close to half of the chlorine used to make chlorinated organics. Most of the EC is produced captively in the synthesis of vinyl chloride monomer.

The direct chlorination of ethylene may be carried out in the liquid phase in the presence of ferric chloride catalyst.

Approximately equimolar proportions of acetylene-free ethylene and chlorine are fed to a tower-type reactor through distributors. The reaction is fast, complete, and exothermic. The tower-type reactor is unique in that the top is a fractionator, complete with vented reflux condenser.

The gas stream from the reactor is passed through a caustic scrubber, where the unreacted gases and traces of HCl are removed. The uncondensed gases (primarily unreacted ethylene and chlorine) are then totally recycled to the reactor.



The liquid stream from the reactor is sent to a distillation column to remove heavy ends and then to a wash tower, where a caustic solution is used to remove some impurities. The crude product is sent to a distillation column for purification. Liquid EC, 99% pure (95% yields), is taken from the top of the fractionation column.

2. Input Materials

Acetylene-free ethylene - 297 kg/metric ton product

Chlorine - 730 kg/metric ton product

Ferric chloride - amount not given

3. Operating Parameters

Temperature of reactor - 90°C (194°F)

Pressure in reactor - 150 kPa (1.48 atm)

4. Utilities

Basis: 72.5 Gg/yr capacity (reactor section)

243 Gg/yr capacity (purification section)

Water: cooling - 21.3 m<sup>3</sup>/minute process and makeup - 450 dm<sup>3</sup>/minute

Steam - 19.5 Mg/hr

Refrigeration - 21.9 MJ (8.09 kWh)

5. Waste Streams

Total hydrocarbon emissions (est.) from the direct process industry -  
13.1 Gg (29 MM lb)/yr (all volatile organics except methane)

Air: vent on reflux condenser

Ethane - 3.0 kg/metric ton EC

Ethylene - 7.5 kg/metric ton EC

Methane - 3.0 kg/metric ton EC

Chlorine - 500 g/metric ton EC

HCl - 500 g/metric ton EC

Water: HCl absorber (scrubber)

Chlorine - 874 g/metric ton EC

EC - 2.45 kg/metric ton EC

HCl - 3.8 kg/metric ton EC

Vinyl chloride (VCM) - 600 g/metric ton EC

Methyl chloride - 50 g/metric ton EC

Ethyl chloride - 50 g/metric ton EC

Purification section - caustic storage

EC - 150 g/metric ton EC

Sodium hydroxide - 600 g/metric ton EC

Sodium chloride - 200 g/metric ton EC

Purification section - filter effluent

EC - 300 g/metric ton EC

Sodium hydroxide - trace

The waste water streams of one plant were surveyed (combined liquid effluents from the reactor offgases scrubber and from the wash tower)

Flow - 3.63 dam<sup>3</sup>/454 kg EC

COD - 6.050 kg/m<sup>3</sup>; 2.9 kg/454 kg EC

BOD<sub>5</sub> - not given

TOC - 1.106 kg/m<sup>3</sup>; 0.40 kg/454 kg EC

Solid: purification section - filter effluent

Mercuric hydroxide - 3.5 g/metric ton EC

Tars - trace

Solids (as carbon) - 50 g/metric ton EC

Purification section - distillation column bottoms

EC - 1.5 kg/metric ton EC

1,1,2-trichloroethane - 2.45 kg/metric ton EC

Tetrachloroethane - 2.45 kg/metric ton EC

Tars - trace

6. EPA Source Classification Code - None

7. References

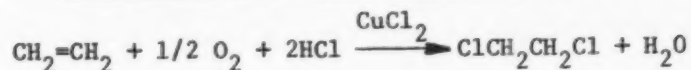
Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corp., Park Ridge, N.J., 1974, p. 146.

Considine, E. M., Ed.-in-Chief, Chemical and Process Technology  
Encyclopedia, McGraw-Hill Book Company, New York, N.Y., 1974,  
p. 1135-1136.

Hedley, W. H., et al., Potential Pollutants from Petrochemical  
Processes, Prepared for EPA, Final Report MRC-DA-406, Contract No.  
68-02-0226, December 1973, p. 194-195.

"Chemical Week," March 12, 1975, p. 35, High Polymers, Leonard, E. C.,  
Editor, Vol. 24, Part 3, p. 1220-1221.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 392.

Ethylene Dichloride (oxychlorination)

1. Function - As of late 1974, one plant of the 12 plants producing EC, used oxychlorination exclusively. The other 11 plants used the oxychlorination of ethylene as part of the "balanced process." The balanced process is a combination of direct addition of chlorine to ethylene and oxychlorination of ethylene. The balanced process acquired its name from the fact that the overall process is balanced to yield only vinyl chloride, (VCM). There is no net production of HCl.

The manufacture of EC exclusively by the oxychlorination process accounted for only 2.4% of the total production in 1974 (108 Mg (240 MM lb) out of 46 Gg (10.045 billion lb)).

Either a fluid bed catalyst or fixed bed catalyst can be used. Approximately stoichiometric proportions of ethylene, anhydrous hydrogen chloride, and air are fed to the "oxy" (catalytic) reactor at low pressure and moderate temperatures. The reactor effluent is cooled generally either by direct water quench or indirect heat exchange. The partially condensed effluent is sent to a phase separator. The gases are contacted with water in a quench column (absorber) for removal of HCl. The resulting hydrochloric acid stream is treated offsite to recuperate the anhydrous hydrogen chloride. The gases are then sent to the EC stripper for recovery of entrained EC which is combined with the EC effluent from the phase separator. Noncondensable gases (mainly nitrogen) are vented to the atmosphere.

The aqueous phase from the decanter is collected in the effluent separator and discharged to waste. The organic phase is usually treated with aqueous caustic soda to remove traces of HCl. It is then sent to product distillation to remove water and chlorinated hydrocarbon impurities which are sent to offsite disposal. The crude EC (96 - 98% purity) is usually combined with the crude EC from the direct chlorination. The combined stream is purified by distillation in an EC finishing column prior to being sent to the cracking furnace for product of VCM (Process No. 133).

2. Input Materials - Basis: Production of 317.5 Mg/yr EC

Ethylene (99.9% purity) - 12.3 Mg/hr;

0.288 metric tons/metric ton EC

Anhydrous hydrogen chloride - 30.5 Mg/hr;

0.711 metric tons/metric ton EC

Air - 42 Mg/hr; 0.961 metric tons/metric ton EC

Dilute caustic soda - 313 kg/hr; 0.007 metric tons/metric ton EC

Catalyst - cupric chloride impregnated on a fluid or fixed bed support

Waste disposal system (direct fired boiler plus scrubber emission control system):

Process vent gas - 36 Mg/hr;  $493 \text{ m}^3$ ;

(17,420 scf)/minute @38°C (100°F)

Caustic feed - 367 kg/hr

Waste disposal system (thermal incinerator and scrubber system):

Combustion air - 14 Mg/hr @27°C (80°F)

Process vent gas - 36 Mg/hr;  $493 \text{ m}^3$ ;

(17,420 scf)/minute @38°C (100°F)

Caustic feed - 367 kg/hr

### 3. Operating Parameters

Reactor outlet temperature - 302°C (575°F)

Reactor temperature - 232 - 315°C (450 - 600°F)

Preheated feed temperature - 149°C (300°F)

Reactor pressure - 239 - 618 kPa (2.36-6.10 atm)

Waste disposal system (direct fired boiler plus scrubber emission control system):

Boiler temperature - 982°C (1800°F)

Flue temperature - 288°C (550°F)

Flue gas temperature from packed scrubbing tower - 60°C (140°F)

Waste disposal system (thermal incinerator and scrubber system):

Incinerator temperature - 982°C (1800°F)

Combustion air and process gas preheat - 149°C (300°F)

Incinerator flue temperature - 871°C (1600°F)

Flue gas temperature from packed scrubbing tower - 77° (170°F)

4. Utilities - not given for overall oxychlorination process; data available on some parts of process based on reactor outlet temperature 302°C.

#### Heat out

Steam generation - 2.82 MG/kg EC

Reactor heat loss - 13.9 kJ/kg EC

Quench plus effluent cooling (302°C to 38°C) - 1.4 MJ/kg EC

#### Heat in

Exothermic heat of reaction

EC formation - 3.21 MJ/kg EC

Effluent neutralization - 4.6 kJ/kg EC

Feed vaporization and preheat (149°C) - 372 kJ/kg EC

Waste disposal system (direct fired boiler plus scrubber emission control system):

Feed water - 21.2 Mg/hr @116°C

Steam generation @1.8 MPa (245 psig) - 20.2 Mg/hr (17.8 atm)

Blowdown - 998 kg/hr @207°C

Natural gas - 420 kg/hr

Incinerator flue gas to packed scrubbing tower - 57.2 Mg/hr;

794 m<sup>3</sup>/min

Quench water - 1.64 Mg/hr

5. Waste Streams - basis: production of 317.5 Mg/yr EC

Air emissions:

Process vent gas - 0.9311 metric tons/metric ton EC

Distillation vent gas - 0.0123 metric tons/metric ton EC

Total hydrocarbon air emissions (est.) from oxychlorination industry  
(all volatile organics) - 43 Gg/yr

Total carbon monoxide emissions (est.) from oxychlorination industry -  
9.9 Gg/yr

Typical composition of process vent gas:



| <u>Component</u> | <u>Composition,<br/>mol. %</u> | <u>Flow rate,<br/>kg/hr</u> |
|------------------|--------------------------------|-----------------------------|
| Carbon dioxide   | 0.6-3.5                        | 957                         |
| Carbon monoxide  | 0.6-1.3                        | 264                         |
| Nitrogen         | 82-95                          | 31.6                        |
| Oxygen           | 0.5-7.5                        | 1.8                         |
| Methane          | 0 -5.0                         | 78                          |
| Ethylene         | 0.2-0.8                        | 191                         |
| Ethane           | 0 -3.8                         | 260                         |
| EC               | 0.07-0.75                      | 272                         |
| Ethyl chloride   | 0 -0.75                        | 231                         |
| Aromatic solvent | 0 -0.75                        | 42.6                        |

Water:

Combined waste water - 0.1908 metric tons/metric ton EC

Waste disposal system - scrubber reject (from thermal incinerator and scrubber system) - 11.9 Mg/hr

Scrubber effluent (from thermal incinerator and scrubber system) - 80 Mg/hr; 1.29 dam<sup>3</sup>/min

Waste disposal system - scrubber reject (from direct fired boiler plus scrubber emission control) - 11.9 Mg/hr

Scrubber effluent (from direct fired boiler plus scrubber emission control) - 62.1 Mg/hr; 906 m<sup>3</sup>/min.

Solids emissions (est.):

Particulates - 181 Mg/yr

6. EPA Source Classification Code - None

7. References

Considine, D. M., Ed.-in-Chief, Chemical and Process Technology Encyclopedia, McGraw-Hill Book Comapny, New York, N.Y., 1974, p. 1137-1138.

Anon., "Engineering and Cost Study Industry, Vol. 3, Ethylene Dichloride Manufacture by Oxychlorination," PB 240, 492, prepared for EPA, Contract 68-02-0255, Air Products and Chemicals Inc., November 1974.

Vinyl Chloride ("Balanced Process")

1. Function - The synthesis of vinyl chloride monomer (VCM) uses an ethylene and chlorine feedstock first to produce ethylene dichloride (EC) which is then pyrolyzed to yield VCM. In the "balanced process" the HCl formed in the cracking of EC, is made to react with more ethylene in the presence of oxygen (oxychlorination reaction) to form more EC.

As of 1975, approximately 94% of the commercial vinyl chloride monomer (VCM) was manufactured by the thermal dehydrochlorination of EC. The other 6% was produced by addition of HCl to acetylene.

If low pressure cracking is used, the VCM and EC are generally removed from the quench vapor stream by condensation or absorption before the remaining HCl is compressed and fed to an oxychlorinating unit. If high pressure cracking is used, the quench vapor stream is fed directly to the distillation unit which consists of two columns, i.e., the anhydrous HCl recovery column, and the VCM recovery column.

In the HCl recovery column, anhydrous HCl is recovered overhead by distillation with refrigerated reflux. The HCl is purified to remove acetylene and vinyl chloride which would yield higher chlorinated by-products in the oxychlorination unit. In the VCM recovery column, EC and other high boiling impurities are separated by fractionation to produce high purity VCM. The EC and higher boiling impurities, as well as the EC and heavy bottoms from the quench

column, are reprocessed in the EC purification unit. Purified EC is recycled to the cracking furnace, and the heavy bottoms (higher chlorinated organics) are sent to waste disposal.

2. Input Materials

Ethylene dichloride - 2700 kg/metric ton VCM

3. Operating Parameters

Temperature of cracking furnace effluent: 500 - 515°C (932-959°F)

Pressure: 2.53 MPa (24 atm)

4. Utilities - Basis: 91 Mg/yr capacity

Total process water usage - 1.27 kg/kg VCM

Total cooling water usage - 1571 kg/kg VCM

Steam: 317 kg/hr

Power: 361 kW (484 hp)

Natural gas: 1.34 dam (47,500 scf)/hr

Refrigeration: 46 kW (130 tons)/hr

5. Waste Streams

Tail gas absorber (air)

Hydrogen chloride - 0.1 kg/metric ton product

Vinyl chloride - 5.0 kg/metric ton product

1,2-Dichloroethylene - 0.15 kg/metric ton product

1,1-Dichloroethylene - 0.4 kg/metric ton product

Acetylene - 1.5 kg/metric ton product

Water - The major waste water sources are the effluents from scrubbing systems required for HCl removal, recycle purification of EC and effluent from associated by-product production units.

Some typical data are:

Flow        1.27 m<sup>3</sup>/454 kg product  
COD        2.733 kg/m<sup>3</sup>  
              3.475 kg/454 kg product  
TOC        0.120 kg/m<sup>3</sup>  
              0.150 kg/454 kg product

Solids (filter solids)

EC - 0.8 kg/metric ton product  
Tars as (C<sub>2</sub>HCl) - 0.05 kg/metric ton product  
Solids (as c) - 0.2 kg/metric ton product

6. EPA Source Classification Code - None

7. References

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, N.J., 1974, p. 214-215.

Considine, D. M., Ed.-in-Chief, Chemical and Process Technology Encyclopedia, McGraw-Hill Book Co., New York, N.Y., 1974, p. 1136-1137.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Final Report MRC-DA-406, prepared for EPA, Contract 68-02-0226, Task No. 9, December 1973, p. 198-199.

Anon., Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Ethylene Dichloride Manufacture by Oxychlorination, PB-240 492, prepared for EPA, Contract No. 68-02-0255, Air Products and Chemicals, Inc., November 1974.

Leonard, E. C., Editor, High Polymers, Vol. XXIV, Part 3, p. 1214-1245.

7. References (continued)

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition  
John Wiley & Sons, New York, N.Y., 1975, p. 868.

"1975 Petrochemical Handbook," Hydrocarbon Processing," November  
1975, p. 213-217.

Ethylene Diamine

1. Function -- Both aqueous and anhydrous ammonia react readily with ethylene dichloride, in both the liquid and vapor phases to form ethylene diamine.

In the vapor-phase reaction ethylene dichloride and an excess of anhydrous ammonia are reacted at 150°C and 9.0 MPa (88.8 atm). Anhydrous ethylene diamine hydrochloride is formed, which, on treatment with caustic soda at 100°C, yields the free amine. The diamine vapors, steam, and unreacted ammonia are led to a dehydrating column where the diamine is dried and condensed.

In the liquid phase process, ethylene dichloride is treated with excess aqueous ammonia at 100°C and 1.0 MPa (9.87 atm). The aqueous product solution containing ethylene diamine hydrochloride, ammonium chloride, and ammonia is heated with caustic soda and fractionated. The ethylene diamine is drawn off and the ammonium chloride is returned to the reaction vessel.

Both processes result in low yields, on the order of 70%. By-products of this reaction include diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenhexamine, and higher polymers.

2. Input Materials

Ethylene dichloride - 2.4 kg/kg product

Ammonia

Water (liquid-phase process)

Sodium hydroxide



3. Operating Parameters

Vapor-phase reaction

Temperature: 150°C (302°F)

Pressure: 9.0 MPa (88.8 atm)

Dehydrochlorination temperature: 100°C

Liquid-phase reaction

Temperature: 100°C (212°F)

Pressure: 1.0 MPa (9.87 atm)

4. Utilities

Not given

5. Waste Streams - Reactor pressure vents, dehydration columns, and distillation columns are probably sources of ammonia, diamine, higher amine, and unreacted ethylene dichloride emissions.

Waste water streams from dehydrochlorination and drying operations undoubtedly contain quantities of caustic soda, and possibly smaller amounts of ammonium chloride, as well as the pollutants previously mentioned.

6. EPA Source Classification Code - None

7. References

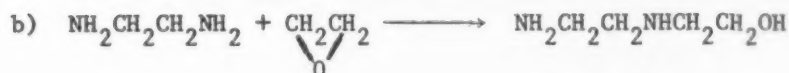
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 5," "Chemical Engineering," April 29, 1974, p. 145, 146.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 7 (1965), p. 31.

U.S. Patent 2,805,254 (September 3, 1957).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition,  
Noyes Development Corp., Park Ridge, N.J., 1969 , p. 313.

Chemical Technology, Barnes and Noble Books, New York, N.Y.,  
Vol. 4 (1972), p. 513.

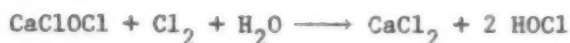
Aminoethylethanolamine

1. Function - Aminoethylethanolamine may be prepared by the reaction of ethylenediamine with ethylene chlorohydrin or ethylene oxide.
2. Input Materials
  - a) Ethylenediamine  
Ethylene chlorohydrin
  - b) Ethylenediamine  
Ethylene oxide
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Waste water may contain traces of acids, products of decomposition, and polymeric products.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 307.

Ibid., Vol. 1 (1963), p. 815.

Houben-Weyl, Methoden Der Organischen Chemie, Vierte Auflage, Georg Thieme Verlag Stuttgart, Bd. 11, T1 (1957), p. 312.

Ethylene Chlorohydrin (from ethylene)

1. Function - Ethylene chlorohydrin is most economically produced by the reaction of ethylene gas and dilute hypochlorous acid in aqueous media. In this process ethylene and chlorine are simultaneously introduced into an aqueous solution of hydrated lime at 20°C and 20.3 MPa so that the ethylene concentration is about 28 g/l alkali. The calcium oxychloride immediately decomposes to calcium chloride and hypochlorous acid which reacts with the ethylene. To avoid excess formation of ethylene dichloride and  $\beta,\beta'$ -dichloroethylene ether, the process is interrupted when a 6-8% solution of ethylene chlorohydrin has been formed, which is quite satisfactory for industrial applications.

Anhydrous ethylene chlorohydrin can be obtained by concentrating the reaction product to 25-30% chlorohydrin, causing an oily layer to separate. This layer is fractionated and the water removed azeotropically with benzene.

2. Input Materials

Ethylene

Chlorine

Water

Lime

3. Operating Parameters

Temperature 20°C (68°F)

Pressure 20.3 MPa (200 atm)

4. Utilities

Not given

5. Waste Streams - Spent catalysts, solvents, various salts, or HCl itself may be present in the waste streams from this operation. The resulting waste water may contain hypochlorous acid, chlorine, spent caustic, HCl, some ethylene chlorohydrin, ethylene dichloride, and  $\beta,\beta'$ -dichloroethyl ether.

Waste products from purification, principally hypochlorous acid and its degradation products (HCl and oxygen), are rejected, and should be present in other waste streams.

6. EPA Source Classification Code - None

7. References

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1974), p. 281.

Faith, W. L. et al., Industrial Chemicals 3rd Ed., John Wiley & Sons, Inc., New York, N.Y., 1965, p. 373.

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Corp., New York, N.Y., 1956, p. 75, 76.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 308.

1,1,2-Trichloroethane (liquid-phase  
chlorination of ethylene dichloride)



1. Function - Most 1,1,2-trichloroethane is made by chlorinating ethylene dichloride in the liquid phase at 120°C and 345 kPa (3.40 atm).

Many variations of this process are in commercial use.

2. Input Materials

Ethylene dichloride - 0.62 kg/kg product

Chlorine - 0.77 kg/kg product

3. Operating Parameters

Temperature: 120°C (248°F)

Pressure: 345 kPa (3.40 atm)

4. Utilities

Basis: 0.59 kg/sec capacity (41 M lb/yr)

Cooling water - 51.2 dm<sup>3</sup>/sec 948.700 gph)

Makeup water - 2.9 dm<sup>3</sup>/sec (2,800 gph)

Steam - 1.36 kg/sec (10,800 lb/hr)

Power - 48 kW

5. Waste Streams - The primary sources of emissions from this process are probably the waste streams from the HCl scrubber. Waste water streams may contain chlorine, HCl, spent caustic, and various chloro-hydrocarbons, including ethylenedichloride, trichloroethane and reaction by-products. Hydrogen chloride and a number of organic chlorides are probably present in the waste gas.

6. EPA Source Classification Code - None

7. References

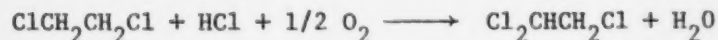
Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 158.

Elkin, L.M., "Chlorinated Solvents," Report No. 48, Stanford Research Institute, Menlo Park, Calif., 1969.



1,1,2-Trichloroethane (oxychlorination  
of ethylene dichloride)



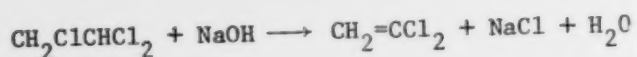
1. Function - Some 1,1,2-trichloroethane is produced by the oxychlorination of ethylene dichloride with HCl. Reaction conditions vary from one process to another.
2. Input Materials  
Ethylene dichloride  
Hydrogen chloride  
Oxygen
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Waste water and vent gases from the separator contain a number of chlorohydrocarbons, including ethylene dichloride, trichloroethane, and by-products.

The crude product is probably scrubbed to remove unreacted acid. Waste water from this operation would contain some HCl.

6. EPA Source Classification Code - None
7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 159.

Vinylidene Chloride (from 1,1,2-trichloroethane)

1. Function - Vinylidene chloride is made by dehydrochlorinating 1,1,2-trichloroethane with lime or aqueous sodium hydroxide at -70°C. A long cylindrical reaction vessel is used. Crude product is separated and purified by distillation under a nitrogen atmosphere and washing with ferrous sulfate and caustic soda solutions.

Purified vinylidene chloride is generally polymerized within 48 hours of its production. If it is to be stored, small amounts of polymerization inhibitors (hydroquinone, alkylamines or organic sulfur derivatives) are added. Peroxide formation has to be monitored. Vinylidene chloride may also be manufactured by continuous chlorination of ethane.

2. Input Materials

1,1,2-trichloroethane - 1.38 kg/kg product

Sodium hydroxide - 0.46 kg/kg product

3. Operating Parameters

Temperature - 70°C (158°F)

Pressure - 101 kPa (1 atm)

4. Utilities - Basis: 0.427 kg/sec capacity (2.97 M lb/yr)

Cooling water - 5.15 dm<sup>3</sup>/sec (4900 gph)

Process water - 1.60 dm<sup>3</sup>/sec (1520 gph)

Power - 305 kW

5. Waste Streams

Vinylidene chloride separation column (water)

Water stream ( $1.69 \text{ dm}^3/\text{sec}$  or 1604 gph) contains

Sodium hydroxide - 45.5 kg/Mg product

Sodium chloride - 605.5 kg/Mg product

Ferrous sulfate and sodium hydroxide may also be present in the wastewater from washing operations.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants From Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 129.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., (1975), p. 838-840.

Perchloroethylene, Trichloroethylene, and Carbon  
Tetrachloride (oxychlorination of ethylene dichloride)



1. Function - Perchloroethylene, trichloroethylene, and carbon tetrachloride are co-produced by the oxychlorination of ethylene dichloride. The chlorine is produced from hydrochloric acid by the Deacon process and combined with ethylene dichloride and additional air in the presence of fluid catalysts.

The actual reaction is highly complex with substitutive chlorination, cracking, Deacon reaction, and carbon burning all occurring simultaneously. Ethylene dichloride, chlorine, oxygen, and recycled chlorinated organics are fed to a fluid bed reactor. An inexpensive oxychlorination catalyst (PPG) is used in the main reaction and the Deacon process catalyst contains copper chloride. The catalysts are contained in a vertical, tubular reactor which operates at moderate pressure and around 425°C (or 600-900°F). Reaction heat generates a large portion of the process steam requirements.

After vent scrubbing, the condensed crude and weak acid are phase separated and the crude dried by azeotropic distillation. The crude is fed to a distillation train where it is split into a perchlor-rich and trichlor-rich stream. The products are separated in stills, neutralized, washed, and dried.

Carbon tetrachloride is recovered as a by-product of this vigorous chlorination.

2. Input Materials - Basis - 1 metric ton  $C_2Cl_4$  (and 793 kg  $C_2HCl_3$ )

Ethylene dichloride - 1195 kg (2,632 lbs)

Chlorine - 692 kg (1,414 lbs)

Oxygen - 388 kg (855 lbs)

Catalysts - Small

3. Operating Parameters

Temperature -  $-425^{\circ}C$  (or  $600-900^{\circ}F$ )

Pressure - moderate

4. Utilities - Not given

5. Waste Streams - Although no information was available, mixed chloro-hydrocarbons, chlorine, and hydrogen chloride may be present in the waste gases of various production components. Heavy ends from the various stills are usually incinerated.

6. EPA Source Classification Code - None

7. References

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 604, 605, 845.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 162.

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973, p. 157.

7. References (continued)

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November, 1975, p. 169.

Belgian Patent 602,840 (April 20, 1961).

Austin, G. T., "The Industrially Significant Organic Chemicals-  
Part 7," "Chemical Engineering," June 24, 1974, p. 156.

Ibid., Part 8, July 22, 1974, p. 115.

1,1,2-Trichloro-1,2,2-Trifluoroethane  
(from perchloroethylene)



1. Function - 1,1,2-Trichloro-1,2,2-trifluoroethane (fluorocarbon 113) is produced by reacting a mixture of hydrogen fluoride and chlorine with perchloroethylene at 225-400°C in the presence of partially-fluorinated antimony pentachloride or zirconium chloride catalyst. The by-product of this reaction is an extremely pure grade of anhydrous HCl which is important in several industrial operations.

The product is purified by distillation and by scrubbing through water and slightly alkaline solution. It is then dried by passage in the liquid phase through beds of silica gel, alumina gel, or synthetic zeolite.

2. Input Materials

Perchloroethylene

Hydrogen fluoride

Chloride

3. Operating Parameters

Temperature: 225-400°C (437-752°F)

Pressure: Not given

Catalyst: Partially fluorinated antimony pentachloride zirconium chloride

4. Utilities

Not given

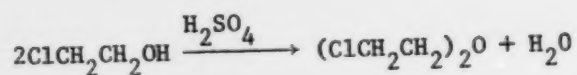


5. Waste Streams - The main pollutant source in this process is probably the scrubber effluent. Waste water streams should contain quantities of caustic soda or other alkali, and perhaps some hydrochloric acid. Various chlorofluorocarbons may be present in low concentrations in both the waste water and vent gas.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 198.

Bis(2-Chloroethyl) Ether

1. Function - In the past, bis(2-chloroethyl) ether has been produced in 75% yield by heating ethylene chlorohydrin with sulfuric acid at 90-100°C.

It has also been prepared by saturating an aqueous solution of ethylene chlorohydrin with chlorine and ethylene. Bis(2-chloroethyl) ether has also been produced by chlorinating ethyl ether in the presence of a catalyst.



2. Input Materials

Ethylene chlorohydrin

Ethyl ether - chlorine

3. Operating Parameters

Not given

4. Utilities

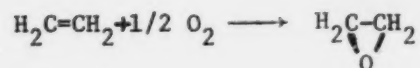
Not given

5. Waste Streams - Although no process description was available, the HCl scrubbers probably contribute to waste water and air emissions. Ethyl ether, chlorine, hydrogen chloride, and some dichloroethyl ether may be present in these emissions.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 487.

Ethylene Oxide (oxidation of ethylene)

1. Function - Presently, ethylene oxide is manufactured by direct vapor-phase oxidation of ethylene over silver oxide catalyst. Approximately 75% of the processes use air as the oxidant, and the remainder use oxygen.

Silver is the only effective high selectivity catalyst. Selectivity is highly sensitive to temperature, dropping as the temperature rises. Therefore, careful temperature control within a narrow range is an absolute necessity. The selection of the carrier is also of considerable importance because of the critical problem of heat removal.

Methods have been sought for retarding the combustion of ethylene to carbon dioxide. Numerous compounds have been proposed, but only ethylene dichloride and polychloroaromatics have been effective on a commercial scale.

A mixture of ethylene, air, and recycle gas (3-5 vol. % ethylene) is pressured and sent to a tubular reactor with a fixed bed, silver catalyst. A heat transfer agent is used to hold the temperature within a narrow range which is adjusted to the temperature/activity relationship of the particular catalyst bed. The reactor effluent gas is cooled by a circulating gas in a heat exchanger. The cooled gas is sent to a scrubbing tower in which the ethylene oxide is scrubbed with water.

The gas that is not absorbed is primarily unreacted ethylene and oxygen. Part of this mixture is returned to the reactor as recycle gas (3-5 mol. % ethylene). The other part is sent forward, reheated in a heat exchanger and sent to a second reactor where oxidation is completed. The effluent is sent to a scrubbing tower where the ethylene oxide is absorbed. The noncondensable gases are purged.

The dilute aqueous ethylene oxide solutions from both scrubbing towers are combined and sent to a stripper (desorber) where ethylene oxide is removed by heating.

The crude ethylene oxide is fractionated on distillation columns. The water from the stripper (desorber) can be returned to the scrubbing towers, or in some cases it is sent to an ethylene glycol plant because this water contains ~2% ethylene glycol.

In the oxygen process, ethylene, oxygen, and recycle gas are fed to the reactor under pressure. The reactor effluent is sent through a carbon dioxide removal system, and is recycled to the reactor to reduce the partial pressure of ethylene. The gases are ultimately sent to a scrubber, thence to the stripper (desorber).

2. Input Materials      Per kg ethylene oxide

|          |                         |
|----------|-------------------------|
| Ag       | $4.37 \times 10^{-4}$ g |
| Air      | 13,100 g                |
| Ethylene | 1,100 g                 |
| Steam    | 100 g                   |
| Water    | $0.208 \text{ m}^3$     |

3. Operating Parameters

Reactor temperature - 104-149°C (219-300°F)

Reactor pressure - 0.929-2.2 MPa (9.2-21.7 atm)

Catalyst - silver oxide supported on inert carriers

4. Utilities

Electricity  $6.74 \times 10^6$  J (1.87 kWh)/kg prod.

5. Waste Streams

Air: Purge gases from air oxidation may contain small amounts of ethylene oxide and ethylene. Ethylene oxide escape from oxide compressor seals. Reactor gas leaks from cycle compressor seals.

Water: The main waste stream is the draw-off from the ethylene oxide separator (stripper; desorber) bottoms. The flow from two plants is given:

|      | <u>Plant 1</u>                             | <u>Plant 2</u>                               |
|------|--------------------------------------------|----------------------------------------------|
| Flow | 67.3 dm<br>454 kg                          | 496 dm<br>454 kg                             |
| COD  | 52 kg/m (52,000 mg/l)<br>3.49 kg<br>454 kg | 4.8 kg/m (4,800 mg/l)<br>2.4 kg<br>454 kg    |
| BOD  | 4.8 kg/m (4,800 mg/l)<br>0.32 kg<br>454 kg | 0.65 kg/m (650 mg/l)<br>0.32 kg<br>454 kg    |
| TOC  | 19 kg/m (19,650 mg/l)<br>1.32 kg<br>454 kg | 2.699 kg/m (2,699 mg/l)<br>1.34 kg<br>454 kg |

Process water usage (including steam) - 0.113 kg/0.45 kg of product

Cooling water - 0.043 kg/0.45 kg of product

6. EPA Source Classification Code - None

7. References

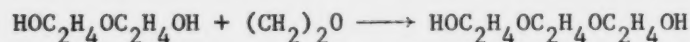
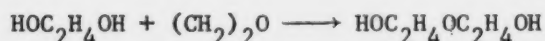
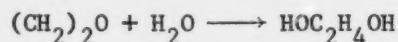
Considine, D. W., Ed.-in-Chief, Chemical and Process Technology Encyclopedia, McGraw-Hill Book Company, New York, N.Y., 1974, pp. 443-446.

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Kent, J. A., Ed., Riegel's Handbook of Industrial Chemistry, Seventh Ed., Van Nostrand Reinhold Company, New York, N.Y., 1974, pp. 779-780.

Sittig, M., "Ethylene Oxide from Ethylene," Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, pp. 150-152.

Faith, W. L., et al., Industrial Chemicals, 3rd Ed., John Wiley & Sons, New York, N.Y., 1965 , p. 382.

Mono-, Di-, and Triethylene Glycols (from hydration of ethylene oxide)

1. Function - Ninety percent of the ethylene glycols produced in the U.S. are made by the direct catalytic oxidation of ethylene to ethylene oxide followed by hydration. Process No. 143 discusses the ethylene to ethylene oxide conversion, so only the hydration step will be considered here:

Ethylene oxide can be converted to glycol by catalytic or non-catalytic hydration. The catalytic process employs a large excess of dilute aqueous acid, usually sulfuric acid and the noncatalytic process employs a large excess of water. The reaction is carried out at 180°C and 2.17 MPa in the liquid phase.

Di- and triethylene glycols are reaction by-products which normally account for 9% and 1%, respectively, of the total product.

However, yields of these ether glycols may be increased by modest alternations (higher temperature and slightly lower pressure) in the reaction conditions. Polyethylene glycols are also formed (in minute quantities only under normal reaction conditions) but their yields may be increased by using a NaOH catalyst (see Process No. 155).



Following reaction, the respective glycols are separated and purified by dehydration of the reaction effluent and vacuum distillation.

2. Input Materials

Ethylene oxide

For ethylene glycol - 0.75 kg/kg

For diethylene glycol - 0.84 kg/kg

For triethylene glycol - 0.90 kg/kg

Water - 2.0 kg/kg product

3. Operating Parameters

|               | Catalytic                                | Noncatalytic                |
|---------------|------------------------------------------|-----------------------------|
| Temperature   | 165-180°C (329-356°F)                    | 95°C (203°F)                |
| Pressure      | 2.17 MPa (21.4 atm)                      | 1.5-2.0 MPa (14.8-19.7 atm) |
| Catalyst      | 0.15-1.0% H <sub>2</sub> SO <sub>4</sub> | ---                         |
| Reaction time | 30 min                                   | ---                         |

4. Utilities

Not given

5. Waste Streams - Dehydration (water)

Water flow - 4.873 m<sup>3</sup>/Mg (2575 gal/ton) product

COD - 8.66 kg/Mg (1b/1000 lb) product

BOD - 0.34 kg/Mg (1b/1000 lb) product

TOC - 4.53 kg/Mg (1b/1000 lb) product

The chief organic pollutants are ethylene glycol ethylene oxide, acetaldehyde, crotonaldehyde, and some sulfuric acid.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals, -  
Part 4," "Chemical Engineering," April 15, 1974, p. 88.

ibid., Part 5, April 29, 1974, p. 146, 147, 148

ibid., Part 9, August 5, 1974, p. 96, 97.

"1973 Petrochemical Handbook Issue," "Hydrocarbon Processing,"  
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Hedley, W. H., et al., Potential Pollutants from Petrochemical  
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Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 642,  
646, 648.

Faith, W.L. et al., Industrial Chemicals, 3rd Ed., John Wiley  
and Sons, New York, N.Y., 1965 , p. 375.

Sittig, M., Organic Chemical Processes, Noyes Press, Inc., Pearl  
River, New York, N.Y., 1962 , p. 59.

Chemical Technology, Barnes & Noble Books, New York, N.Y., Vol. 4  
(1972), p. 293, 337, 339.

Ethylene Glycol Mono- And Diacetates

1. Function - Ethylene glycol mono- and diacetates are coproduced by any of the standard methods of esterification of hydroxyl groups such as esterification with acid halides, acid anhydride, and acids.

The ester and diester are separated by distillation.

2. Input Materials

Ethylene glycol

Acetic acid (glacial)

3. Operating Parameters - Not given

4. Utilities - Not given

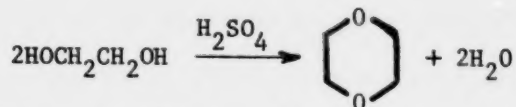
5. Waste Streams - Air and wastewater emissions may contain ethylene glycol, acetic acid, and ethylene glycol mono- or diacetate.

6. EPA Source Classification Code - None

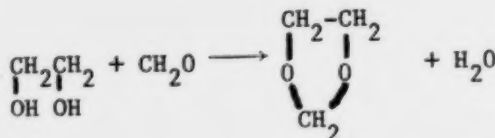
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 10 (1966), p. 645.

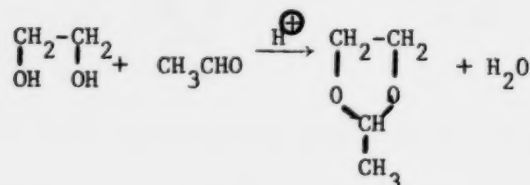
Curme, George O., Johnston, F., Glycols, ACS Monograph 114, Reinhold Publishing Corp., 1952, p. 128.

Dioxane (from ethylene glycol)

1. Function - 1,4-Dioxane is produced on a commercial scale by heating ethylene glycol in the presence of a dehydration catalyst such as sulfuric acid.
2. Input Material  
Ethylene glycol
3. Operating Parameters  
Temperature: 160°C (320°F)  
Pressure: Not given  
Catalyst: H<sub>2</sub>SO<sub>4</sub> (4% by weight of ethylene glycol)
4. Utilities  
Not given
5. Waste Streams - The separator water effluent may contain quantities of sulfuric acid, ethylene glycol, and dioxane.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 643.  
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4, (1972), p. 352.

1,3-Dioxolane

1. Function - Ethylene glycol derivatives react with aliphatic and aromatic aldehydes or ketones to give 1,3 dioxolanes.
2. Input Materials  
Ethylene glycol  
Formaldehyde
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Wastewater from the separator may contain unreacted formaldehyde and ethylene glycol, and possibly, dioxolane. Some air emissions may also result from this operation.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 639.  
Van der Plas, H. C., Ring Transformations of Heterocycles, Academic Press, 1973 p. 17.  
U.S. Patent 3,324,145 (June 6, 1967).

2-Methyl-1,3-Dioxolane

1. Function 2-Methyl-1,3-dioxolane is derived from the reaction of ethylene glycol and acetaldehyde.
2. Input Materials  
Ethyl glycol  
Acetaldehyde
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - The separator may release a waste stream containing acetaldehyde, ethylene glycol, and some methylidioxolane.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 639-646.  
Van der Plas, H. C., Ring Transformations of Heterocycles, Academic Press, Vol. 1 (1973), p. 17.

Ethylene Glycol and Diethylene Glycol Monoethers

1. Function - Ethylene glycol monoethers are made by reacting ethylene oxide and anhydrous alcohol under a variety of reaction conditions. The reaction proceeds spontaneously at 180°C - 200°C and 3.0 - 4.0 MPa (435-580 psig), but can be carried out at 100 - 150°C in the presence of an acid or base catalyst (caustic soda or boron trifluoride). Alcohols commonly used to produce glycol monoethers include methanol, ethanol, propanol, butanol, hexanol, octanol, and phenol.

Diethylene glycol monoethers are by-products of ethylene glycol monoether production, normally accounting for 10 - 15% of the total product. Higher polyglycol monoethers (2-3%) are also formed. The yield of di- and polyglycol monoethers may be increased by lowering the ratio of alcohol to ethylene oxide.

Of the 230 million lbs. of glycol ethers produced in 1965, 78% were ethylene glycol monomethyl ethers, 19% were diethylene glycol ethers, and 3% were triethylene glycol ethers.

2. Input Materials - Ethylene oxide

|                                        |              |
|----------------------------------------|--------------|
| For ethylene glycol monomethyl ether   | - 0.58 kg/kg |
| For ethylene glycol monoethyl ether    | - 0.54 kg/kg |
| For ethylene glycol monobutyl ether    | - 0.41 kg/kg |
| For diethylene glycol monomethyl ether | - 0.74 kg/kg |
| For diethylene glycol monoethyl ether  | - 0.69 kg/kg |
| For diethylene glycol monobutyl ether  | - 0.59 kg/kg |
| Other ethylene glycol monoethers       | - 0.39 kg/kg |



Alcohol

For ethylene glycol monoethers -

Methanol, ethanol, propanol, hexanol, octanol, phenol

For diethylene glycol monomers -

Methanol, ethanol, butanol, hexanol

3. Operating Parameters - Noncatalytic Process

Temperature - 180-200°C (356-392°F)

Pressure - 3-4 MPa (29.6-39.5 atm)

Catalytic process

Temperature - 100-150°C (212-302°F)

Pressure - not given

Catalyst - acid or base

4. Utilities - not given

5. Waste Streams - No information was available, but waste streams may contain ethylene oxide, ethylene and higher polyglycols, alcohols, glycol monoethers, reaction by-products, and traces of acid or base catalyst.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 5,"

"Chemical Engineering," April 29, 1974, p. 150.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,

Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 643.

7. References (continued)

Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4,  
(1972). p. 336.

Hahn, A. V., The Petrochemical Industry: Markets and Economics, McGraw-  
Hill Book Co., New York, N.Y., 1970, p. 282.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 403, 404.

Mono-, Di-, and Triethylene Glycol Diethers

$n = 1, 2, 3$

R = methyl, ethyl, butyl

1. Function - Glycol diethers may be prepared by the general methods of ether preparation, but the preferred method is by reacting an alkyl chloride with the sodium salt of the corresponding glycol mono-ether.

2. Input Materials

Mono, di- or triethylene monoether sodium glycolate

Alkyl chloride

3. Operating Parameters - Not given

4. Utilities - Not given

5. Waste Streams - Wastewaters contain sodium chloride, alkyl chloride, and possibly other reactants and products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 10 (1966), p. 643.

Curme, George O., Johnston, F., Glycols in ACS Monograph 114, Reinhold Publishing Corp., 1952, p. 118.

Mono- and Diethylene Glycol Monoether Acetates

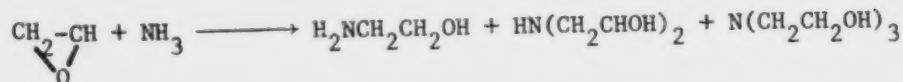
R = methyl, ethyl, butyl

n = 1, 2

1. Function - Glycol monoether acetates are made by esterifying the glycol monoethers with acetic acid. The reaction is similar to that used to produce ethylene glycol acetate and diacetate. See Process No. 145.
2. Input Materials  
Mono- or diethylene glycol monoether  
Acetic acid
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - The waste water stream from the separator may contain any of the reactants or products.
6. EPA Source Classification Code - None
7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Curme, G. O. and Johnston, F., Glycols, ACS Monograph Series 114, Reinhold Publishing Corp., New York, N.Y., 1952, p. 163.

Ethanolamines (from ethylene oxide)

1. Function - Monoethanolamine is produced together with di- and triethanolamines by a reaction between ethylene oxide and an excess of aqueous ammonia at 50-100°C. The yield is about 95% based on ethylene oxide.

Excess ammonia is stripped from the reaction effluent. The overhead from the ammonia stripper, together with fresh ammonia makeup, enters an ammonia absorber where the aqueous ammonia solution is prepared for reaction. The bottoms from the ammonia stripper are first evaporated to produce a recycle water stream and are then dried in a separate column. A product distillation train of three columns produces the three products, recycle amine streams, and rejected heavies.

The product mixture can be partially controlled by temperature, the ratio of ammonia to ethylene oxide, and recirculation of products. A large excess of ammonia favors monoethanolamine production. Recirculation of this product shifts the reaction equilibrium in favor of di- and triethanolamines.

2. Input Materials

Ethylene oxide

For monoethanolamine - -.75 kg/kg

For diethanolamine - 0.88 kg/kg

For triethanolamine - 0.93 kg/kg

Aqueous  $\text{NH}_3$

3. Operating Parameters

Temperature: 50-100°C (122-212°F)

Pressure: Not given 1.03-2.07 MPa (10.2-20.4 atm)

4. Utilities

Not given

5. Waste Streams - Some atmospheric emissions probably result from stripping, evaporating, drying, and fractionating operations. Ammonia and traces of the various ethanolamines may be present in these waste gases. Rejected heavies from still bottoms are primarily higher amine ethers.

6. EPA Source Classification Code

None

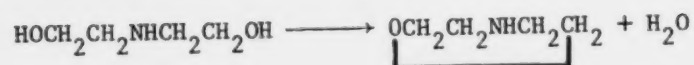
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 4," "Chemical Engineering," April 15, 1974, p. 87,88.

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973, p. 120.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973, p. 136, 137.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 814.

Morpholine (from diethanolamine)

1. Function - Morpholine is almost exclusively made by dehydration of diethanolamine with sulfuric acid.

The reaction mixture is neutralized to give an aqueous solution of morpholine. Morpholine is extracted with organic solvents and purified by distillation.

2. Input Materials

Diethanolamine

95%  $\text{H}_2\text{SO}_4$

3. Operating Parameters

Temperature - 150-180°C (302-356°F)

Pressure - not given

4. Utilities - Not given

5. Waste Streams - Waste water may contain alkali sulfate from neutralization as well as traces of diethanolamine, morpholine, and the organic solvent used in distillation.

6. EPA Source Classification Code - None

7. References

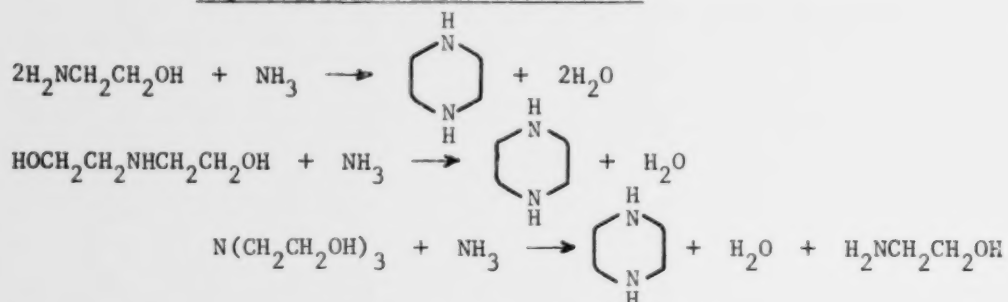
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 662.

Weissberger, A., Editor, The Chemistry of Heterocyclic Compounds, Interscience Publishers, New York, N.Y., Vol. 17 (1962), p. 378.



7. References (continued)

Waddams, A. L., Industrial Organic Chemicals, 3rd Edition, John Wiley and Sons, New York, N.Y., 1973, p. 89.

Piperazine (from ethanolamines)

1. Function - Piperazine is produced by treating mono-, di- or tri-ethanolamines with excess ammonia over a Ni/Cu/Cr catalyst.
2. Input Material

Ethanolamines

Ammonia (excess)

Catalyst (Ni/Cu/Cr)
3. Operating Parameters

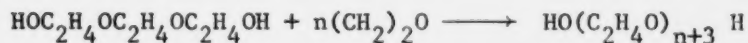
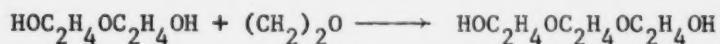
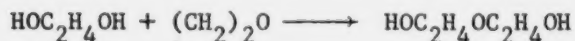
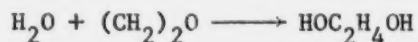
Temperature: 200-260°C (392-500°F)

Pressure: 10.3-41.4 MPa (102.1-408.3 atm)
4. Utilities - Not given
5. Waste Streams - The only wastes should be some unreacted ethanolamines, ammonia, and catalysts.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 15 (1968), p. 640, 641.

U. S. Patent 3,151,115 (September 29, 1964).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1961, p. 531.

Polyethylene Glycol (hydration of ethylene oxide)

1. Function - Like di- and triethylene glycols, polyethylene glycol is a by-product of ethylene glycol production. For significant conversion to the polyglycol, however, ethylene oxide and water must be combined in the presence of sodium hydroxide catalyst.

2. Input Materials

Ethylene oxide - 1.10 kg/kg

Water

3. Operating Parameters

Temperature: 120-150°C (248-302°F)

Pressure: 294 kPa (2.9 atm)

Catalyst: NaOH

4. Utilities

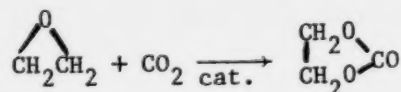
Not given

5. Waste Streams - Process slops may carry ethylene glycol and sodium hydroxide.

6. EPA Source Classification Code - None

7. Reference

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 655.

Ethylene Carbonate (from ethylene oxide)

1. Function - Ethylene oxide reacts with carbon dioxide under pressure and in the presence of a catalyst to give ethylene carbonate.

The product is centrifuged to remove the catalyst and the crude product distilled in vacuum to give pure ethylene carbonate.

2. Input Materials

Ethylene oxide

Carbon dioxide

3. Operating Parameters

Temperature - 190-220°C

Pressure - 13.2 MPa (130 atm)

Catalyst - LiI

4. Utilities - Not given

5. Waste Streams - Waste water may contain traces of ethylene carbonate, ethylene glycol, ethylene oxide, and carbon monoxide.

6. EPA Source Classification Code - None

7. References

U.S. Patent 3,025,305 (1962).

German Patent 1,135,490.

SECTION V  
METHANE



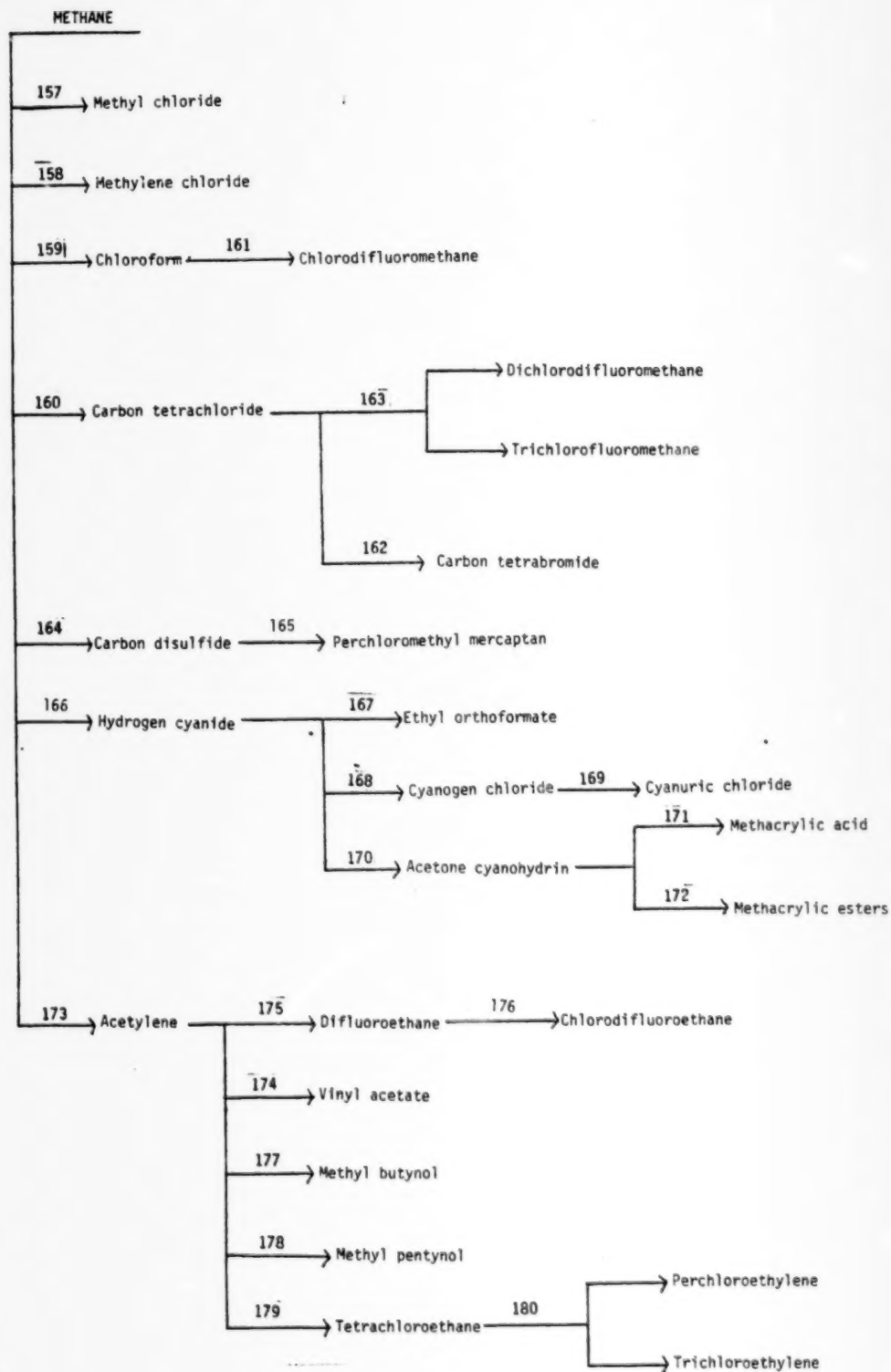


Figure 9. Methane Section Chemical Tree

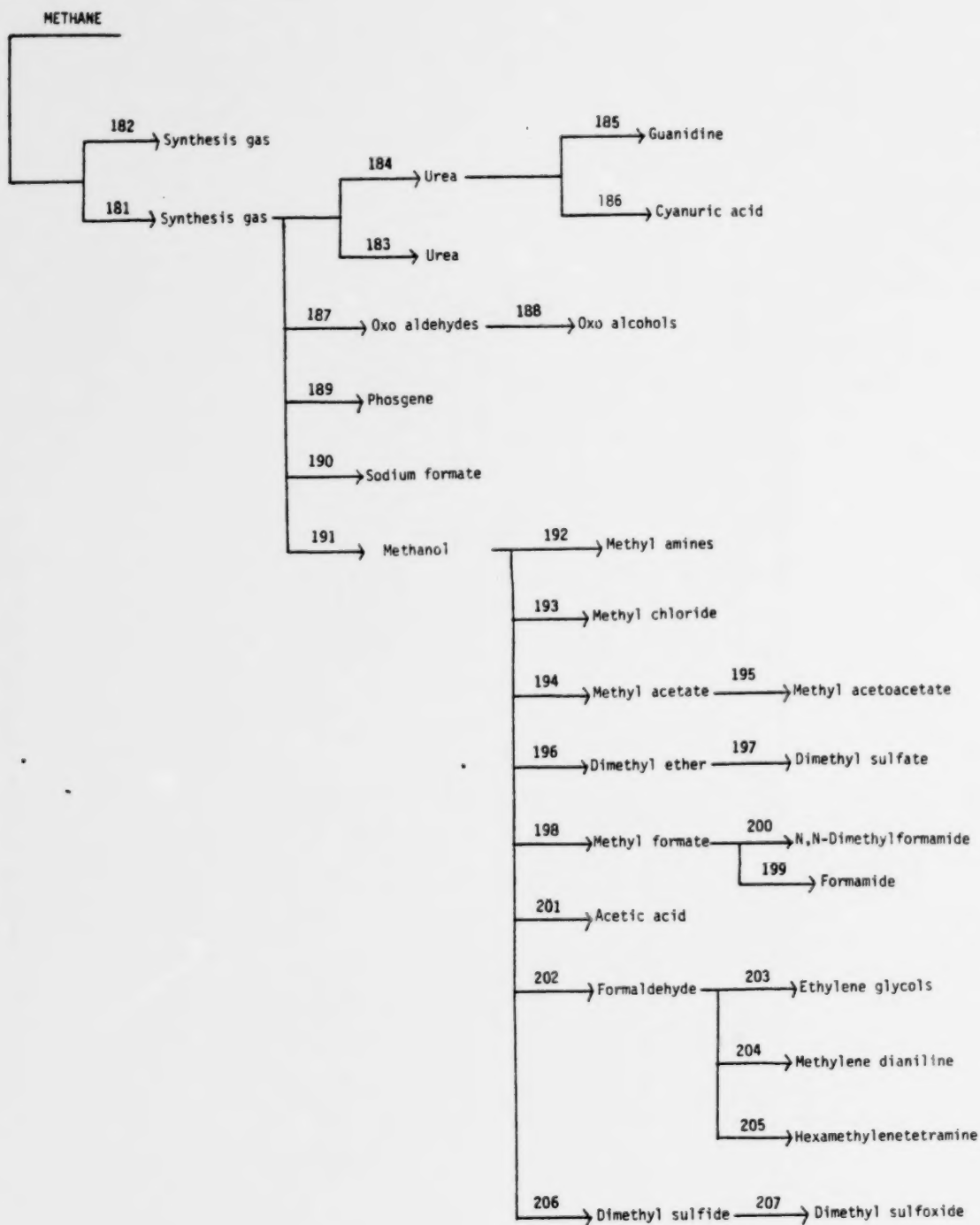


Figure 9. Methane Section Chemical Tree (Cont.)

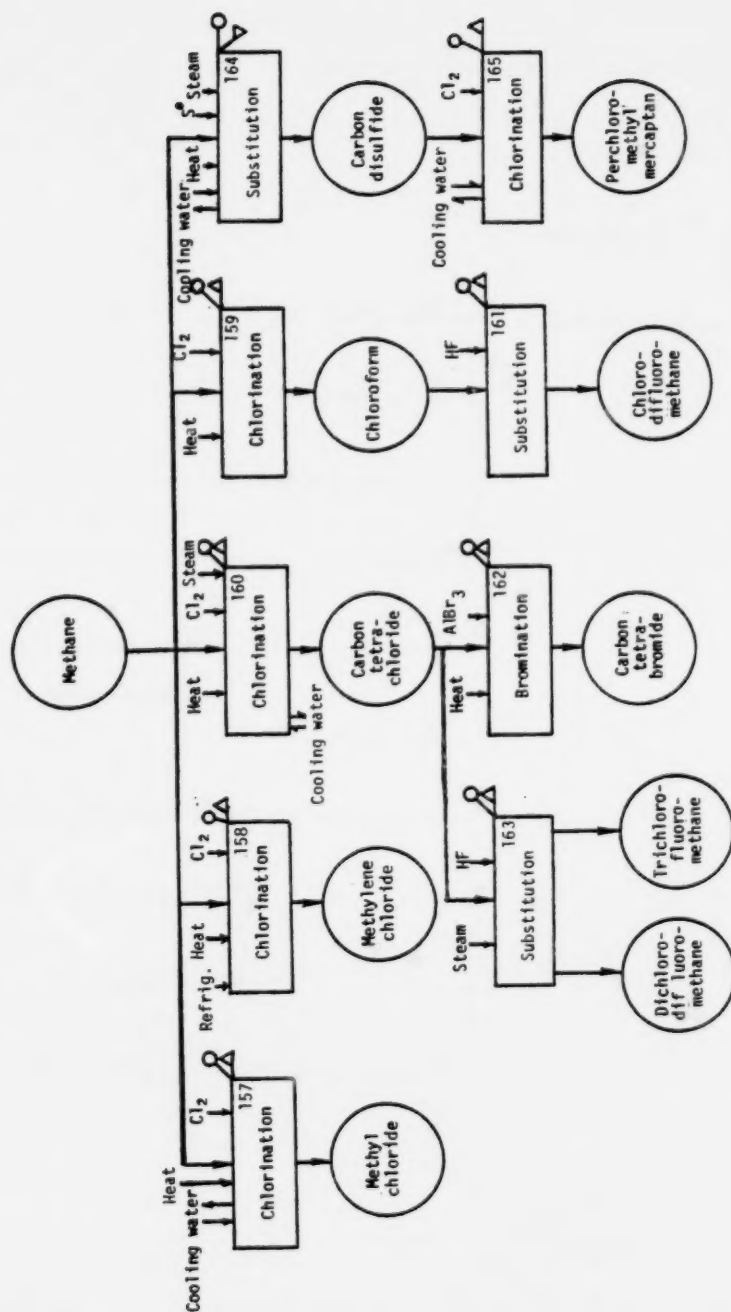


Figure 10. Methane Section Process Flow Sheet

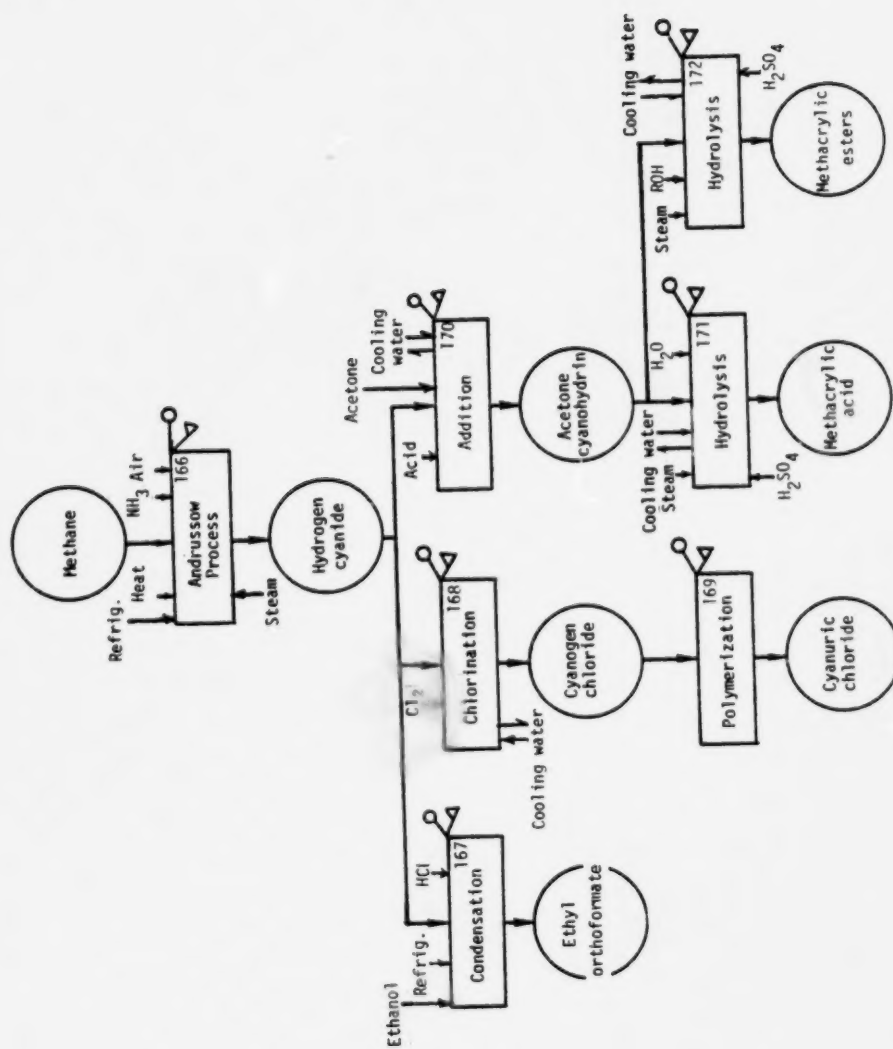


Figure 10. Methane Section Process Flow Sheet (Cont.)

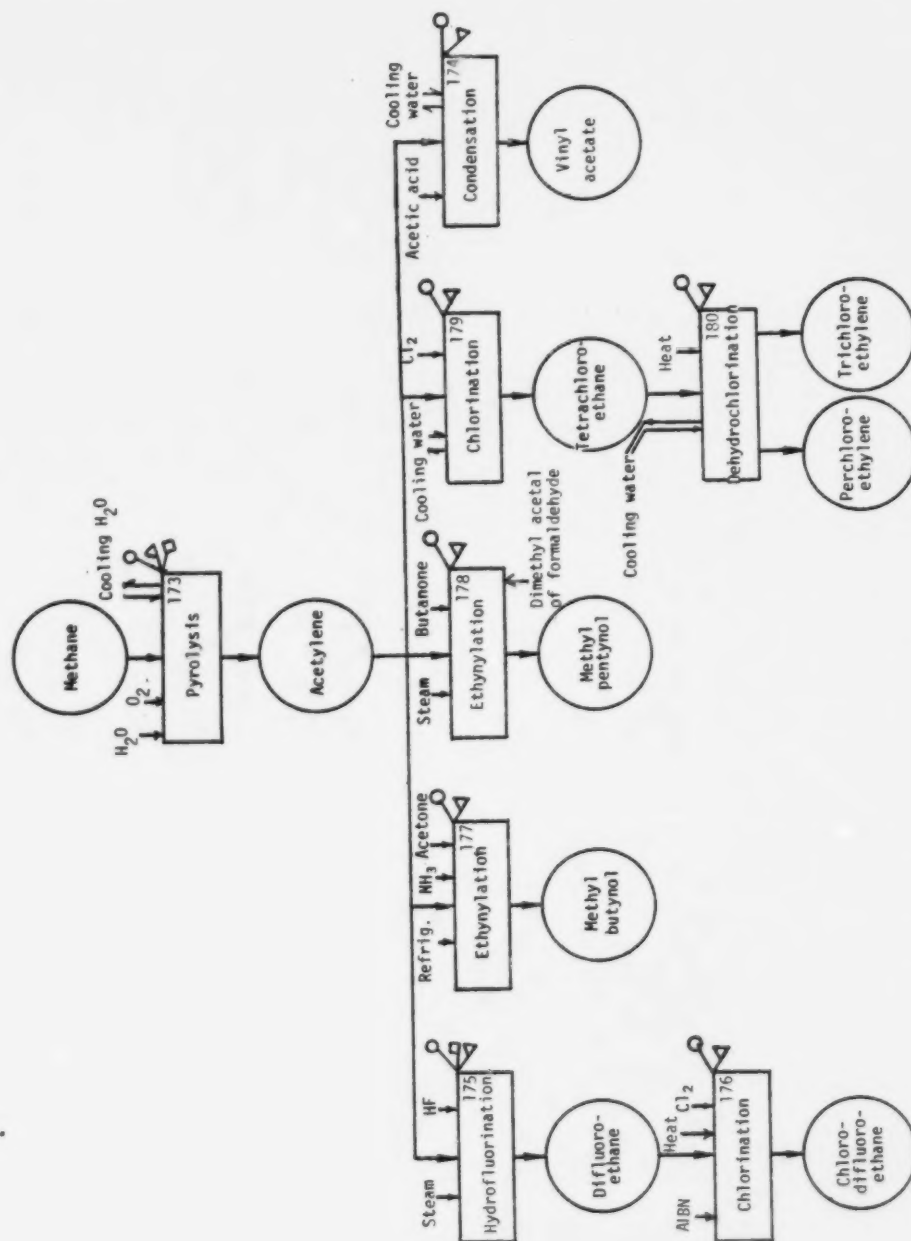


Figure 10. Methane Section Process Flow Sheet (Cont.)

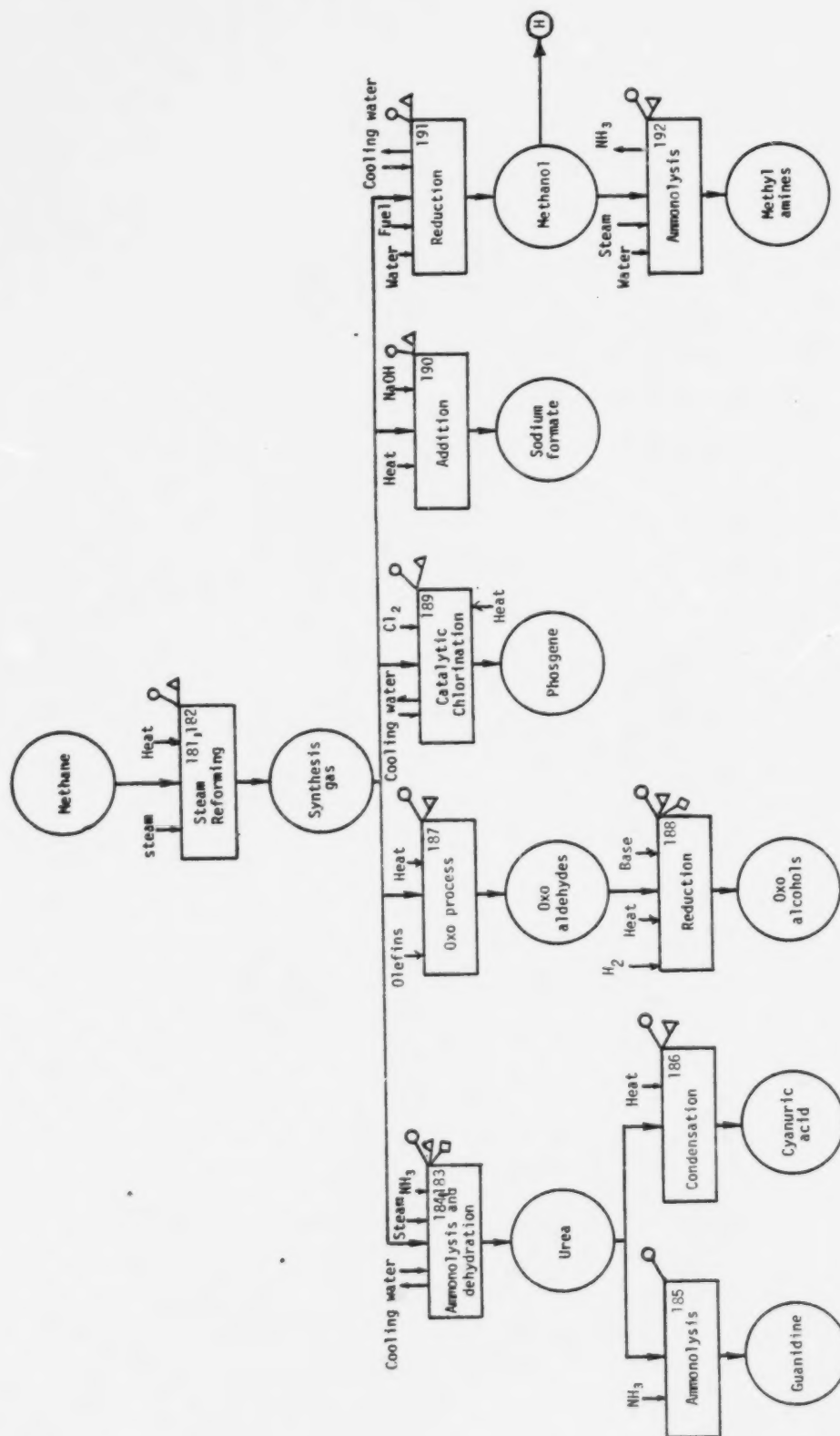


Figure 10. Methane Section Process Flow Sheet (Cont.)

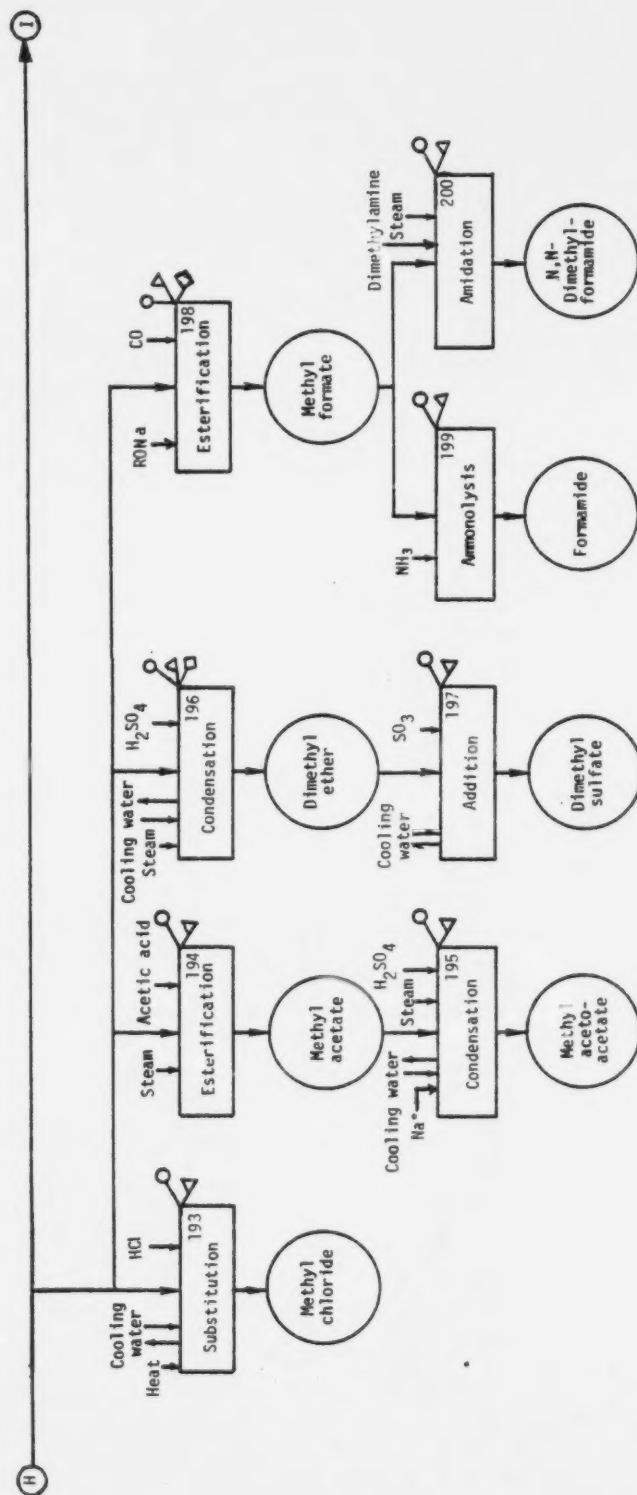


Figure 10. Methane Section Process Flow Sheet (Cont.)



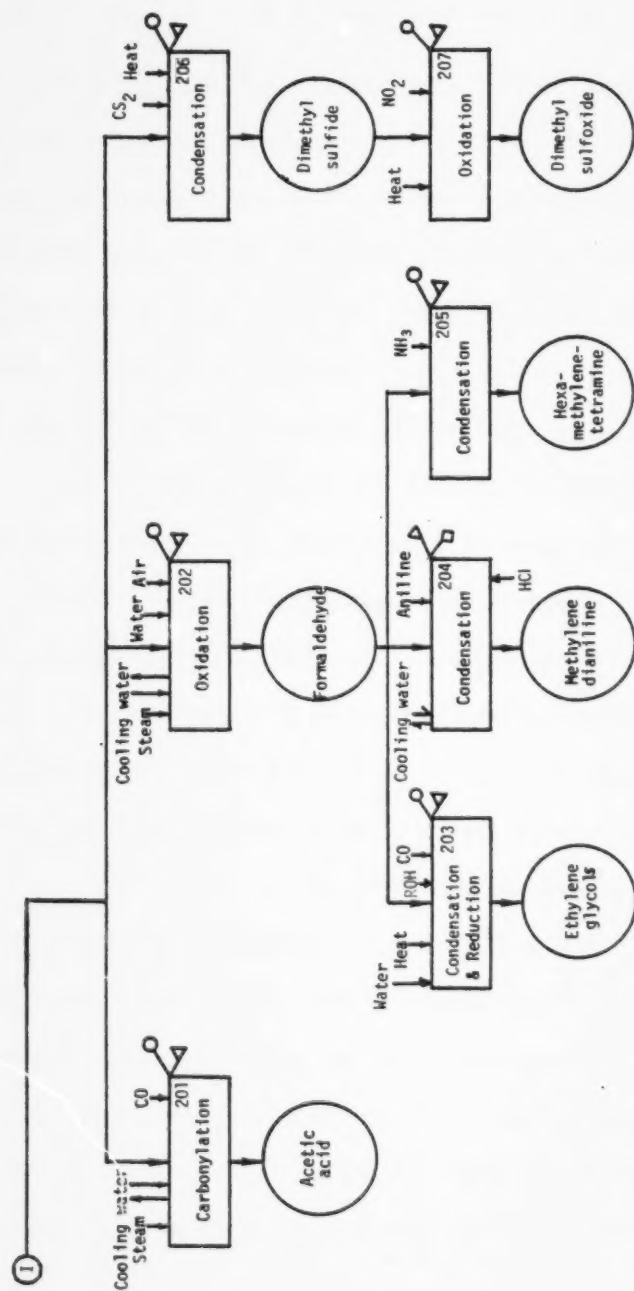


Figure 10. Methane Section Process Flow Sheet (Cont.)

Methyl Chloride

1. Function - As of 1970, chloromethane was made either by the chlorination of methane (70%) or the hydrochlorination of methanol (22%).

The chlorination of methane process sequence requires four main steps; reaction, HCl recovery, chlorides recovery and chlorides refining. High purity methane, chlorine and recycle methane are pre-mixed and fed to the reactor. The reactor effluent, containing organic chlorides, HCl, excess methane, and only traces of chlorine, is cooled and fed to the HCl recovery system.

The first column in this system is an absorber designed for efficient HCl removal. The bulk of the absorbing liquor is HCl azeotrope (about 20 percent by weight HCl). The rich acid is thus above the azeotrope and allows stripping of anhydrous HCl. The second column distills off anhydrous HCl and produces the required azeotrope in the bottoms. For high yields of methyl chloride, the amount of recirculating methane is increased.

The HCl-free gases from the absorber are washed with caustic soda to remove final traces of HCl and are then ready for chlorides recovery by compression, cooling, and drying with sulfuric acid.

2. Input Materials - Basis - 1 metric ton methyl chloride

|                                              |                                                   |
|----------------------------------------------|---------------------------------------------------|
| Methane - 179 kg/Mg (358 lb/ton) product     | 1445 m <sup>3</sup> (15,713 ft <sup>3</sup> /ton) |
| Chlorine - 1587 kg/Mg (3,174 lb/ton) product | 1405 kg (3,097 lbs/ton)                           |
| Sulfuric Acid                                |                                                   |
| Caustic Soda                                 |                                                   |

3. Operating Parameters

Temperature - 400 - 500°C (752-932°F)

Pressure - 200 kPa (2 atm)

Flow Rate - not given

Catalyst - None

4. Utilities

Electric Power - not given

Cooling Water - not given

5. Waste Streams

Dehydrator (air)

Purge on recycled methane to remove inerts

CH<sub>4</sub> - 1 kg/Mg (2 lb/ton) product

CH<sub>3</sub>Cl - 13 kg/Mg (26 lb/ton) product

CH<sub>2</sub>Cl<sub>2</sub> - 2 kg/Mg (4 lb/ton) product

CHCl<sub>3</sub> - 1 kg/Mg (2 lb/ton) product

CCl<sub>4</sub> - 1 kg/Mg (2 lb/ton) product

Waste acid solution is discharged from the dehydrator.

Waste caustic solution is discharged from the washer where traces of HCl are removed from the product gases.

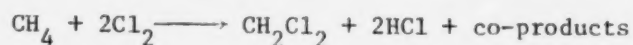
6. EPA Source Classification - None

7. References

Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corporation, Park Ridge, N.J., 1974, p. 105.

Austin, G. T., "Industrially Significant Organic Chemicals - Part 3,"  
"Chemical Engineering," March 18, 1974, p. 89,90.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 531,532.

Methylene Chloride (chlorination of methane)

1. Function - Processes for  $\text{CH}_2\text{Cl}_2$  manufacture are based on chlorination of methane, although the other chloromethanes are probable co-products of this route, their relative proportions are determined by process operating conditions.

A typical methane chlorination synthesis of methylene chloride and co-products is as follows. A preheated mixture of methane and chlorine passes into a vessel where reaction is promoted by a control of feed-gas flow rate and the reactor temperature. In addition to chloromethanes, the exit gas contains unreacted methane and hydrogen chloride. Initial separation of the product group from  $\text{CH}_4$  and  $\text{HCl}$  is generally affected by scrubbing the effluent gas with a refrigerated mixture of higher chloromethanes, in which the methane and hydrogen chloride are only slightly soluble. The methane, freed from acid by water scrubbing, is recycled to the chlorinator and the chloromethanes, containing the desired  $\text{CH}_2\text{Cl}_2$ , after washing, alkali scrubbing, and drying, pass to a sequence of fractionating columns.

2. Input Materials

Methane - 0.179 kg/kg product

Chlorine - 1.587 kg/kg product

3. Operating Parameters

Temperature: 360 - 500°C (680 - 932°F)

Pressure: 205 kPa (2 atm)

Catalyst: UV light from mercury vapor lamps

4. Utilities

Not given

5. Waste Streams - Scrubbing water effluent with chloromethanes to remove methane and hydrogen chloride from the desired products results in the following emissions.

$\text{CH}_4$  - 1 g/kg product

$\text{CH}_3\text{Cl}$  - 13 g/kg product

$\text{CH}_2\text{Cl}_2$  - 2 g/kg product

$\text{CHCl}_3$  - 1 g/kg product

$\text{CCl}_4$  - 1 g/kg product

Water scrubbing to free HCl from methane stream should lead to emissions of  $\text{Cl}_2$  and a waste acid solution. Alkali used in neutralizing the latter and in scrubbing the  $\text{CH}_2\text{Cl}_2$  - containing stream yield spent caustic as a further pollutant.

Note that methylene chloride forms toxic products, such as phosgene, when exposed to hot surfaces or open flames.

6. EPA Source Classification Code - None

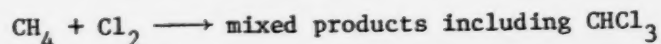
7. References

Hedley, W. H., et. al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 115.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7," Chemical Engineering, June 29, 1974, p. 154.

"Air Pollution from Chlorination Processes," prepared for Office of Air Program, Environmental Protection Agency, Contract No. CPA 70-1, Task Order No. 23, March, 1972.

Chloroform (chlorination of methane)

1. Function - Chloroform was formerly made by reaction of chlorinated lime (bleaching powder) and acetone, acetaldehyde, or ethanol, but this appears to be uneconomical in most cases. Currently, chlorination of methane is the principal route to chloroform, with other chloromethanes usually co-produced. Control of the chlorine/methane feed ratio and other operating conditions influence the yield of  $\text{CHCl}_3$ . A two-stage chlorination provides the maximum yield. Purification of chloroform is accomplished by extraction with concentrated sulfuric acid followed by repeated distillation.

Chloroform may also be made by substituting methanol for methane.

2. Input Materials - Basis - 1 metric ton chloroform

Methane -  $187 \text{ m}^3$  ( $6,604 \text{ ft}^3$ )

Chlorine - 1780 kg (3924 lbs)

3. Operating Parameters

Temperature: elevated ( $250 - 800^\circ\text{C}$  ?) ( $482 - 1472^\circ\text{F}$ )

Pressure: not given

Catalyst: ultraviolet light (optional)

4. Utilities

Not given

5. Waste Streams - Various chloromethanes might be emitted from the methane chlorinator. Neutralization of sulfuric acid used in purification and by-product hydrochloric acid may lead to spent caustic and traces of acid in the waste water flow.



Note that chloroform slowly oxidizes to phosgene on exposure to sunlight.

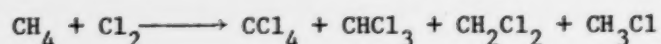
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3," "Chemical Engineering," March 18, 1974, p. 89.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November 1975, p. 127.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 266.

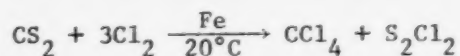
Carbon Tetrachloride (chlorination of methane)

1. Function - Since the 1950's chlorination of hydrocarbons, particularly methane, has been a more important production route to carbon tetrachloride in the United States than chlorination of carbon disulfide. The chemical process is referred to as chloranalysis, which involves the simultaneous breakdown of hydrocarbons and chlorination of molecular fragments. As methane and chlorine react in this manner, some carbon tetrachloride is produced, along with varying amounts of other chloromethanes. The relative quantities depend on the composition of the hydrocarbon starting material and the conditions of chlorination. With a  $\text{Cl}_2/\text{CH}_4$  molar ratio of 0.6, and a reaction temperature of 340-370°C, the following yields are obtained:  $\text{CCl}_4$ -2%,  $\text{CHCl}_3$ -10%,  $\text{CH}_2\text{Cl}_2$ -29%,  $\text{CH}_3\text{Cl}$ -58%. Recycling partially chlorinated materials and using light as a catalyst permits essentially complete conversion to carbon tetrachloride. The gas flow must be rapid to keep the likelihood of an explosion to a minimum. This process requires corrosion resistant metals (Ni) and exacting controls since the reaction is quite exothermic.

In Hüls process, a 5:1 ratio of  $\text{Cl}_2$  to  $\text{CH}_4$  by volume is reacted at 650°C, the temperature being controlled by regulating the gas flow rate. A heat exchanger cools the exit gas to 450°C before it is passed to a second reactor for the addition of more methane. Perchloroethylene is the principal co-product in this case.

Crude carbon tetrachloride is generally purified by neutralization and drying, followed by distillation. Additional purification can be obtained at the distillation stage by maintaining the carbon tetrachloride for a prolonged period under total reflux before actually starting the distillation itself. Decomposition of carbon tetrachloride upon contact with water or on heating in air make it practical to add a small quantity of stabilizer to the commercial product.

Carbon tetrachloride may also be prepared from carbon disulfide:



Carbon tetrachloride is also a by-product of the vigorous chlorination and dehydrochlorination of ethylene dichloride and the Deacon process.

2. Input Materials - Basis - 1 metric ton product

Methane - 110 kg (242.5 lbs)

Chlorine - 2.210 kg (4872 lbs)

3. Operating Parameters

Temperature - 250-650°C (482-1202°F)

Pressure - atmospheric

Catalyst - light (optional)

Reaction time - very short

4. Utilities - Basis - 1,000 kg  $\text{CCl}_4$

Electricity, GJ - 0.486 (135 kWh)

Steam (1.2 MPa, 12 bar), kg-135 (298 lbs)

Steam (0.95 MPa, 4.5 bar), kg-135 (298 lbs)

Cooling water,  $\text{m}^3$  - 85 (22,457 gal)

Fuel, GJ-0.837 ( $2 \times 10^5$  kcal)

5. Waste Streams - Various chloromethanes emitted from the process during the early repeated-chlorination stage (8 lbs./100 lbs. product). An alkali of some sort is used to neutralize hydrochloric acid (118 lbs./100 lbs. product) which is formed by the chlorination reaction and traces of the spent liquid might appear in wastewater flow.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 127.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 132,133.

Faith, W. L., et. al., Industrial Chemicals, 3rd Ed., John Wiley & Sons, Inc., New York, N.Y., 1965, p. 229-231.

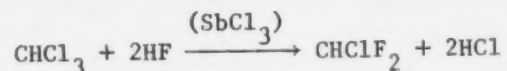
Sittig, M., Organic Chemical Processes, Noyes Press, Inc., Pearl River, N.Y., 1972, p. 39,40.

7. References (continued)

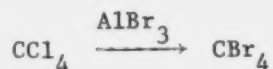
"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973,  
p. 156-157.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November 1975,  
p. 126.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 232.

Chlorodifluoromethane (chloroform and hydrogen fluoride)

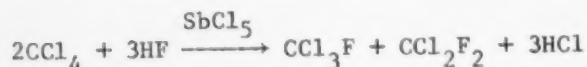
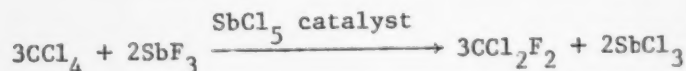
1. Function - Chlorodifluoromethane is derived by reaction of chloroform with anhydrous hydrogen fluoride, catalyzed by antimony trichloride.
2. Input Materials  
Chloroform  
Anhydrous hydrogen fluoride
3. Operating Parameters  
Temperature: not given  
Pressure: not given  
Catalyst:  $\text{SbCl}_3$
4. Utilities - not given
5. Waste Streams - Various chlorofluoromethanes are potential gaseous emittants. By-product hydrochloric acid and caustic solution used in neutralization may appear in waste water streams.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 9 (1966), p. 743, 746.

Carbon Tetrabromide (from carbon tetrachloride)

1. Function - Carbon tetrachloride reacts with aluminum tribromide at high temperature to yield carbon tetrabromide.
2. Input Materials  
Carbon tetrachloride  
Aluminum tribromide
3. Operating Parameters  
Temperature - 100°C (212°F)  
Pressure - Not given
4. Utilities - Not given
5. Waste Streams - The various bromethanes are possible emissions from this process. Carbon tetrachloride, aluminum hydroxide, and possibly some HBr or Br<sub>2</sub> may be present in the waste streams.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 131.



Dichlorodifluoromethane and Trichlorofluoromethane  
(catalytic fluorination of carbon tetrachloride)



1. Function - Preparation of these two chlorofluoromethanes is not by direct fluorination but rather by the replacement of chlorine atom of carbon tetrachloride with fluorine due to the action of  $\text{SbF}_3$  containing antimony pentahalide, either  $\text{SbCl}_5$  or  $\text{SbF}_5$ , as catalyst. The industrial process uses liquid hydrogen fluoride as an inexpensive source of fluorine and involves continuous regeneration of a small initial batch of  $\text{SbF}_3$ .

The process is usually conducted at about  $100^\circ\text{C}$  and from 0 to 3.45 MPa (0-34.0 atm) with gaseous HF. Dichlorodifluoromethane and hydrochloric acid, which is insoluble in liquid HF, are taken off to a column which readily separates the partially fluorinated substance  $\text{CCl}_3\text{F}$ .

2. Input Materials - Basis - 1 metric ton dichlorodifluoromethane  
Carbon tetrachloride  $\text{CCl}_4$  - 1600 kg (3527 lbs)  
Antimony (III) fluoride  $\text{SbF}_3$  - small  
Hydrogen fluoride - 413 kg (911 lbs)

3. Operating Parameters

Temperature: 0-100°C (0-212°F)

Pressure: 0-3.45 MPa (0-34.0 atm)

Catalyst:  $\text{SbCl}_5$  (or  $\text{SbF}_5$ )

4. Utilities - Not given

5. Waste Streams - Hydrogen chloride produced, which is insoluble in liquid HF, must be removed and neutralized before ultimate disposal, leading to possible pollution of waste liquid flow by HCl, spent caustic, and perhaps traces of dissolved HF. Any gas-phase reaction is a potential source of chlorofluorohydrocarbons to be emitted to the air.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 4," "Chemical Engineering," April 15, 1974, p. 86, 87.

U.S. Patent 3,381,044 (April 30, 1968).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 232.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 325, 326.

Carbon Disulfide (catalytic methane-sulfur reaction)

1. Function - The basic production of  $\text{CS}_2$  in the United States is currently limited to the catalytic reaction of methane (or natural gas) and sulfur vapor; this Thacker process having almost completely (70%) replaced the older charcoal-sulfur retort method. This system provides yields of over 90 mole percent carbon disulfide per pass with the use of active catalysts such as silica gel. The process usually operates in the temperature range 500-700°C, and the pressure may be about 170 kPa (25 psi). Space velocities, based on hydrocarbon gas charge, in this case methane, are on the order of 100-400 volumes of gas per hour per unit volume of catalyst. Sulfur is usually charged in slightly higher than stoichiometric amounts.

The hydrogen sulfide formed may be used as an end product or it may be reconverted to elemental sulfur, for recycle to the reaction system, in a separate partial oxidation unit using the Claus process. This involves burning  $\text{H}_2\text{S}$  with air to form sulfur dioxide, which then reacts with the remaining  $\text{H}_2\text{S}$ , at about 300°C in the presence of catalyst, to form sulfur. The Claus process permits about 95% conversion to sulfur based on the hydrogen sulfide charge.

The process flow for the carbon disulfide formation reaction is as follows. Molten sulfur, maintained at about 130°C, is transferred to a sulfur boiler where it is vaporized and further heated to 575-650°C to convert the sulfur vapor to the diatomic form. Methane, or natural

gas from which higher molecular weight paraffins are substantially removed, is preheated to 550-650°C and mixed with the sulfur vapor. The mixed stream, with or without additional heating, is passed downward through a fixed-bed catalytic reactor for the formation of CS<sub>2</sub>. The reason for avoiding higher molecular weight hydrocarbons in the feed is that under specified conditions, these are more reactive than CH<sub>4</sub> and will combine with sulfur to produce polymerization and condensation products, leading to catalyst contamination.

The reactor effluent is cooled to about 130°C and the unreacted sulfur is separated in a gas-sulfur separator and recycled to the process. Simultaneously, small amounts of sulfur dust in the product stream are removed by scrubbing with liquid sulfur. The carbon disulfide is separated from H<sub>2</sub>S by preferential absorption in a suitable mineral oil solvent from which it is subsequently stripped and sent to a distillation section.

The stripped carbon disulfide is separated from small amounts of impurities in two successive distillations with low-boiling impurities removed overhead in the first column. The bottoms material from this section is distilled in a second column where the final high-purity CS<sub>2</sub> is recovered as the distillate. The off-gas from the carbon disulfide absorber contains 90-95% H<sub>2</sub>S and passes to the sulfur recovery unit.

Due to the corrosive nature of sulfur and hydrogen sulfide at high temperatures, stainless-steel alloys are employed in the preheaters and reactor units. High-chromium (25% Cr) and stabilized nickel-chromium alloys are satisfactory.

2. Input Materials - Basis - 1 metric ton CS<sub>2</sub>

Methane: (or natural gas stripped of higher molecular weight paraffins)  
345 m<sup>3</sup> (12,184 ft<sup>3</sup>)

Sulfur: (vapor) 925 kg (2,039 lbs)

3. Operating Parameters

Temperature: 500-700°C (932-1292°F)

Pressure: 130-300 kPa (1.28-2.96 atm)

Catalyst: activated Al<sub>2</sub>O<sub>3</sub> + Cr<sub>2</sub>O<sub>3</sub>

(others - alumina, silica-alumina, bauxite, silica-zirconia)

Hourly space velocity: 600 per hr.

4. Utilities

Not given

5. Waste Streams - Carbon disulfide manufacture contains a large number of potential emission sources and hence pollutants. The sulfur boiler and the introduction of recycle sulfur at the start of the process flow may lead to sulfur vapor escaping. Heating the methane or natural gas feed stream could be a source of gaseous hydrocarbons. Light mercaptans and heavy di-acid polysulfides are formed. The Claus sulfur recovery unit and the purification of carbon disulfide by staged distillation should give off undetermined amounts of sulfur compounds, including H<sub>2</sub>S and SO<sub>2</sub>.

6. EPA Source Classification Code - None

7. References

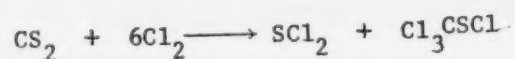
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 127.

7. References (continued)

Kirk-Othmer, Encyclopedia of Chemical Technology, Interscience Publishers, New York, N.Y., Vol. 4 (1964), p. 376-378.

Hahn, A. V., The Petrochemical Industry: Markets and Economics, McGraw-Hill Book Co., New York, N.Y., 1970, p. 168,169.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 224,225.

Perchloromethyl Mercaptan (chlorination of carbon disulfide)

1. Function - Perchloromethyl mercaptan is prepared by the chlorination of carbon disulfide at 20°C in the presence of iodine as a catalyst. The reaction is carried out in glass-lined jacketed vessels. Chlorination is continued until 3-5% excess chlorine is present. (The excess chlorine converts any  $\text{S}_2\text{Cl}_2$  to  $\text{SCl}_2$ ).

The reaction mixture is then fractionally distilled under a 20 in. vacuum to remove the  $\text{SCl}_2$ , excess chlorine, unreacted  $\text{CS}_2$  and  $\text{CCl}_4$ . An 85% yield of 97-98% purity product is obtained. Perchloromethyl mercaptan is an intermediate for the fungicide Captan.

2. Input Materials

Carbon disulfide

Chlorine

3. Operating Parameters

Temperature - 20°C (68°F)

Pressure (for distillation) - 2.66 kPa (0.026 atm)

Catalyst - Iodine

4. Utilities - Not given

5. Waste Streams - Emission probably contains traces of reactants, hydrolysis products of chlorinated compounds, and sulfur from decomposition of

$\text{S}_2\text{Cl}_2$ .



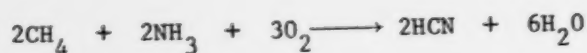
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 374.

Senning, A., Editor, Sulfur in Organic and Inorganic Chemistry, Marcel Dekker, Inc., New York, N. Y., Vol. 1, 1971, p. 244.

Kharasch, N. and Meyers, C.Y., The Chemistry of Organic Sulfur Compounds, Vol. 1, 1961, p. 362-364.

Hydrogen Cyanide (reaction of methane, ammonia, and air)

1. Function - As of January 1971, 70% of the hydrogen cyanide produced in the United States was manufactured via the Andrussow process. In the process a mixture of air,  $\text{CH}_4$ , and  $\text{NH}_3$  in a volume ratio of 6:1:0.9 is passed over the catalytic surface at a pressure of about 250 kPa (22 psig) and gas velocity of .53 m/sec. A typical catalyst consists of a number of layers of woven, 80-mesh 90% platinum - 10% rhodium gauze made of 3-mil wire. The hot gases from the reactor are quenched (to prevent polymerization of HCN), and unreacted ammonia is removed (as  $(\text{NH}_4)_2\text{SO}_4$ ) or recycled. The off-gas, with ammonia removed goes to a cold water acidic absorber to remove HCN which is then stripped and fractionated by conventional means. Assuming recycle of unreacted  $\text{NH}_3$ , the ultimate yield of HCN can be 87% of the theoretical value. The DEGUSSA and Fluohmic processes are variations of the Andrussow process.

2. Input Material - Basis - 1 metric ton HCN (99.5%)

Methane -  $115\text{m}^3$

Air -  $7500\text{ m}^3$

Ammonia - 830 kg (assuming 75% yield)

Phosphoric acid, 85% (stabilizer)

Sulfuric acid, sp.gr.1.7 - 725 kg

3. Operating Parameters

Temperature - 1000-1200°C (1832-2192°F)

Pressure - ~250 kPa (2.47 atm)

Gas feed velocity - .53 m/sec.

Catalyst: Pt/Rh mesh

4. Utilities - Not given

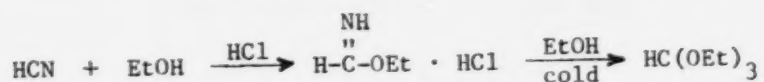
5. Waste Streams - Possible air emissions -  $\text{NH}_3$ ,  $\text{CH}_4$ ,  $\text{H}_2$ , HCN, CO. Waste water - solutions of sulfuric acid, and ammonium sulfate.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 576-580.

Lowenheim, F. A. and Moran, M. M., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N. Y., 1975, p. 482-486.

Ethyl Orthoformate (from HCN/HCl/EtOH)

1. Function - Ethyl orthoformate is prepared in a two-step process by reacting hydrogen cyanide, ethanol, and hydrochloric acid at room temperature followed by reaction with ethanol in the cold.
2. Input Material  
Hydrogen cyanide  
Ethanol  
Hydrochloric acid
3. Operating Parameters  
Temperature: 1st Step - room temperature  
2nd Step - reduced temperature
4. Utilities - Not given
5. Waste Streams - Unreacted HCN, EtOH, and HCl should be present along with ammonia and/or ammonium salts.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 6 (1965), p. 574.

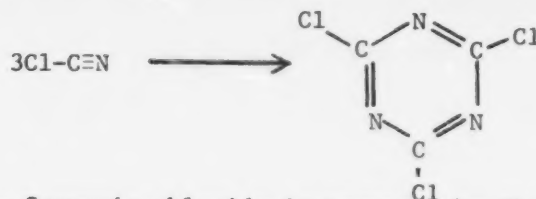
Cyanogen Chloride (chlorination of hydrogen cyanide)

1. Function - Cyanogen chloride is readily formed by the reaction of hydrogen cyanide and chlorine in the liquid phase. A possible preliminary stage in cyanogen chloride manufacture is the reaction of hydrogen cyanide with sodium hydroxide in aqueous solution to form NaCN. Sodium cyanide may then be chlorinated in aqueous solution (pH <8.5) to give NCCl.
2. Input Materials  
Hydrogen cyanide  
Chlorine
3. Operating Parameters  
Not given
4. Utilities  
Not given
5. Waste Streams - Chlorine gas, HCN, and NCCl are all possible airborne emissions. Wastewater will probably contain trace of hydrogen cyanide as well as spent caustic and sodium chloride from scrubbing operations used to neutralize the hydrochloric acid by-product.
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 3.

Hahn, A. V., The Petrochemical Industry: Markets and Economics,  
McGraw-Hill Book Co., New York, N.Y., 1970, p. 160.

Cyanuric Chloride (polymerization of cyanogen chloride)

1. Function - Cyanuric chloride is prepared by the vapor phase polymerization of cyanogen chloride.
2. Input Materials  
Cyanogen chloride  
Charcoal carrier impregnated with 3.75%  $\text{CaCl}_2$ ,  $\text{BaCl}_2$ , or  $\text{S}_2\text{Cl}_2$
3. Operating Parameters  
Temperature: 250-480°C (482-896°F).
4. Utilities - Not given.
5. Waste Streams - Spent polymerization catalysts may be present in process wastes. Possible atmospheric emissions include cyanogen chloride and by-products.
6. EPA Source Classification Code - None.
7. References  
British Patent 602,816 (June 3, 1948).

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 20 (1969), p. 667.

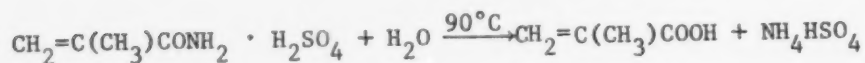
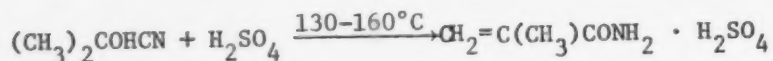


Acetone Cyanohydrin

1. Function - Acetone cyanohydrin is manufactured on an industrial scale by the base-catalyzed condensation of acetone and hydrogen cyanide. The reaction temperature is normally kept under 40°C. The product must be acidified to prevent decomposition.
2. Input Materials  
Acetone - 0.6 kg/kg product  
Hydrogen cyanide  
Unspecified acid
3. Operating Parameters  
Temperature: < 40°C (104°F)  
Pressure: atmospheric pressure  
Catalyst: caustic soda
4. Utilities  
Not given
5. Waste Streams - Information available on this process was too limited to identify specific pollutant sources. However, reactants are probably present in air emissions from reactor vents and purification procedures.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 672.

7. References (continued)

Waddams, A. L., Chemicals from Petroleum, 3rd Ed., John Murray Ltd.,  
London, Eng., 1973, p. 127.

Methacrylic Acid (from acetone cyanohydrin)

1. Function - In the preparation of methacrylic acid, acetone cyanohydrin and concentrated sulfuric acid are pumped to a hydrolysis kettle where they react to form methacrylamide sulfate. This conversion is usually carried out at 130 - 150° C.

After cooling, the crude intermediate is taken to a second reactor where it combines with water to form methacrylic acid and ammonium bisulfate.

The product stream is then pumped to the acid-stripping column where methacrylic acid and some water distill. The residue, made up of sulfuric acid, ammonium bisulfate, and water, is sent to the ammonium sulfate plant.

The overhead from the acid-stripping column enters a rectifier column where methacrylic acid comes over the top, is condensed, and is sent to the wash column. Crude methacrylic acid comes off on the top of the wash column, and is shipped to other plants for further distillation. The water solution from the bottom of the column is recycled to the rectified column to complete methacrylic acid recovery.

Polymerization inhibitors are added at the acid-stripping column and the rectified columns.

2. Input Materials

Acetone cyanohydrin - 1.18 kg/kg product

Sulfuric acid

Water

Polymerization inhibitors

3. Operating Parameters

Temperature: first reactor - 130-160° C (266-320°F)

second reactor - 90° C (194°F)

Pressure: Not given

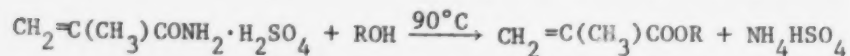
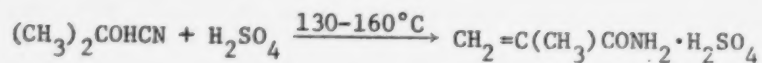
4. Utilities - Not given

5. Waste streams - The waste water stream from the rectifier column probably contains small quantities of methacrylic acid and polymerization inhibitors. Traces of methacrylic acid and other organics may be discharged to the air by various processing equipment.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 333.

Methacrylic Esters (from acetone cyanohydrin)

1. Function - Methacrylic esters are prepared from acetone cyanohydrin in the same manner as methacrylic acid (see Process No. 171). In this process variation, the methacrylamide sulfate intermediate is reacted with ethyl, n-butyl, isobutyl, n-hexyl, or n-lauryl alcohol rather than water to yield the corresponding ester.\*

Ester recovery operations are essentially the same as those used in methacrylic acid purification. An alcohol recovery section is necessary, however, to strip excess alcohol from the rectifier bottoms for recycle.

2. Input Materials

Acetone cyanohydrin

Sulfuric acid

Water

Alcohol

Polymerization inhibitors

3. Operating Parameters - see Process No. 171

4. Utilities

Cooling water - 166 kg/kg product

Steam -0.25 kg/kg product

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\* Many other alcohols are also used.

5. Waste Streams - Waste water from the alcohol-recovery column probably contains some methacrylic acid, alcohol, and polymerization inhibitors. Traces of alcohol and methacrylic acid may also be discharged through reactor and various distillation column vents. Sulfuric acid is discharged in waste water streams.

COD -  $1.78 \times 10^5$  mg/l

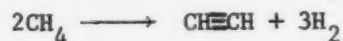
BOD<sub>5</sub> -  $2.07 \times 10^4$  mg/l

TOC -  $6.99 \times 10^4$  mg/l

6. EPA Source Classification Code - None

7. References

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, N.J., 1974, p. 164-166.

Acetylene (BASF process)

1. Function - In the United States, the initial commercial production of acetylene from hydrocarbon sources began in 1951. Today, most of the manufacture of acetylene for chemical synthesis is based on the process researched by Badische Anilin-und Soda-Fabrik (BASF) in the 1920's.

In this so-called partial oxidation, or one-stage combustion method, the necessary energy for cracking the feedstock is derived by partial combustion of the hydrocarbon feed. Natural gas or other methane-rich feedstock is mixed with a limited amount of oxygen sufficient for complete combustion, and fed through a specially designed distributor or burner to a single reaction zone in which ignition occurs. Improved results are claimed for variations which involve preheating of the separate gas streams (Societe Belge de l'Azote, SBA) or preheating the premixed composite feed (Hydrocarbon Research, Inc.). The Montecatini process, in addition employs pressure operations of up to six atmospheres and effects partial cooling of the burner gas by injecting higher hydrocarbons after the flame, resulting in production of ethylene and additional acetylene.

Design of the burner is of considerable importance and is a common point of process variation. Preignition, stability, and blow-off of the flame, the possibility of backfiring through the burner head ports, and deposition of carbon on the burner walls all depend



on the burner design and the gas and flame velocities. The combustion of the gas mixture must be as uniform as possible across the reaction chamber so that the residence time of the reactant hydrocarbon is as short as possible, usually on the order of 1 to 10 milliseconds.

Yields of acetylene based on carbon in the natural gas feed vary from 30 - 36% by weight for the various processes. The composition of the cracked gas produced from a natural gas feedstock by the BASF one-stage combustion process is given in the following table:

Composition of BASF Process Gas

| <u>Component</u>  | <u>% by Volume</u> |
|-------------------|--------------------|
| acetylene         | 8.5                |
| hydrogen          | 57.0               |
| carbon monoxide   | 25.3               |
| carbon dioxide    | 3.0                |
| methane           | 4.0                |
| higher acetylenes | 1.0                |
| inert material    | 1.0                |

The actual operation of the BASF convertor begins with separate preheating of methane and oxygen (95 - 98% pure) to about 650°C. The feed streams are then mixed in a venturi-type chamber in a molar ratio of about 0.6:1.0, oxygen to methane. The mixed gas is passed to the flame space through a number of tubular channels in a burner block. About one third of the methane entering the burner is cracked to acetylene, the remainder is burned with O<sub>2</sub>. The pyrolysis products

are immediately quenched to about 280°C by one or more water sprays located in the lower part of the reactor, and the effluent gases pass through scrubbers for the removal of water and soot. Higher acetylenes present in the pyrolysis gas must be removed because of this tendency to polymerize. Electrostatic units, combined with water scrubbers, moving coke beds, and bag filters, are being used for soot removal.

The unstable, explosive nature of acetylene imposes certain limitations on the use of customary separation techniques. Studies indicate that operating conditions where acetylene partial pressure exceeds 100 to 200 kPa or where temperatures exceed 95 - 105°C should be avoided. All commercial processes for the recovery of hydrocarbon-derived acetylene are based on absorption/desorption techniques using one or more selective solvents (i.e., dimethylformamide).

2. Input Materials

Methane - 4.11 kg/kg acetylene produced

Oxygen - 4.75 kg/kg acetylene produced

3. Operating Parameters

Temperature: 1480 - 1540°C (2,696-2,804°F)

Pressure: reduced

4. Utilities - Not given

5. Waste Streams - Hydrocarbons from the feedstock may be emitted to the air. Water spray used to quench the reaction mixture may pick up traces of dissolved gases, such as carbon oxides, hydrogen,

5. Waste Streams (continued)

or hydrocarbons, which would eventually find their way to waste water streams. Carbon black may give rise to particulates suspended in air or water.

Flow -  $0.0047 \text{ m}^3/\text{kg}$  (561 gal/ $10^3$  lbs)

COD - 1,274 mg/l

5.95 g/kg

BOD<sub>5</sub> - 410 mg/l

1.92 g/kg

TOC - 393 mg/l

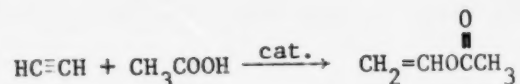
1.80 g/kg

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 178-180.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 30-33.

Vinyl Acetate (from acetylene)

1. Function - Until 1967 vinyl acetate was produced in the United States predominantly from acetylene. By 1973 about 75% of the vinyl acetate was manufactured by the vapor-phase oxyacetylation of ethylene.

In the acetylene process, the acetylene is specially purified to remove  $\text{H}_2\text{S}$  and phosphorus compounds. It is then mixed with gaseous acetic acid and fed into a fixed-bed reactor with zinc acetate on carbon as catalyst. Reactor temperature is maintained at 175-200°C. The reactor effluent is condensed, light ends removed, and vinyl acetate distilled.

2. Input Materials

Acetylene - 325 kg/metric ton vinyl acetate

Acetic acid - 710 kg/metric ton vinyl acetate

3. Operating Parameters

Temperature - 175-200°C (347-392°F)

Pressure - not given

Catalyst - Zinc acetate on carbon

4. Utilities - not given

5. Waste Streams - Waste gases may contain traces of light ends (methyl acetylene, allene, acetylene). Waste waters may contain traces of acetic acid.

6. EPA Source Classification Code - None

7. References

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 862-867.

Waddam, A. L., Chemicals from Petroleum, 3rd Edition, John Wiley & Sons, New York, N. Y., 1973, p. 42.

1,1-Difluoroethane (hydrofluoric acid and acetylene)

1. Function - 1,1-Difluoroethane is derived by passing acetylene and a selected catalyst into the bottom of a stainless steel column of liquid hydrogen fluoride. The gaseous reaction products are washed with soda lime, distilled and condensed.

2. Input Materials - Basis - 0.93 part.

Acetylene: 1 part  
Hydrogen fluoride: 1.6 parts  
 $\text{BF}_3$  (10%): 0.52 parts

3. Operating Parameters

Temperature: 0-20°C (0.68°F)  
Pressure: 68.9-517 kPa (0.58-5.10 atm)  
Catalyst: Anhydrous stannic-chloride  
Contact Time: 20 sec.

4. Utilities - Not given.

5. Waste Streams - Acetylene, difluorethane, and HF may be emitted to the atmosphere. Soda lime sludge should be present.

6. EPA Source Classification Code - None.

7. References

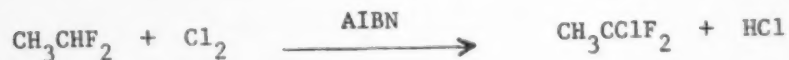
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 9 (1966), p. 835.

U. S. Patent 2,830,099 (April 8, 1958).

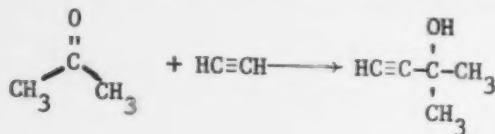
U. S. Patent 2,425,991 (1947).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd  
Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 246.



1,1,1-Chlorodifluoroethane (chlorination of difluoroethane)

1. Function - 1,1,1-Chlorodifluoroethane is prepared by chlorinating 1,1-difluoroethane in the presence of azobis-isobutyronitrile (AIBN).
2. Input Materials  
Difluoroethane  
Chlorine
3. Operating Parameters  
Temperature: 70-100°C (158-212°F)  
Pressure: 2.59 - 3.79 MPa (25.5-37.9 atm)  
Catalyst: AIBN  
Reaction Time: 2-8 seconds.
4. Utilities - Not given.
5. Waste Streams - Spent caustic and salt are pollutants from the scrubber used to remove hydrochloric acid by-product. Some chlorine may be emitted to the air as well as chlorinated compounds, acetylene and vinyl chloride.
6. EPA Source Classification Code - None.
7. References  
Sittig, M., Organic Chemical Process Encyclopedia - 1969,  
2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969,  
p. 169.

Methyl Butynol (ethynylation of acetone)

1. Function - 2-Methyl-3-butyn-2-ol is produced by ethynylation of acetone with excess acetylene in liquid ammonia in the presence of sodamide ( $\text{NaNH}_2$ ) or some other basic catalyst. The reaction is carried out at a temperature of 10-40°C and high pressure (1.97 MPa).

The process is terminated by adding a material to decompose the catalyst. The pressure is then dropped to atmospheric in a suitable flash tank. Ammonia and excess acetylene are recycled to the reactor, and unreacted acetone is removed from the product in a distillation column. A second distillation step takes the methyl butynol overhead as an azeotrope containing 28.4% water, leaving behind deactivated catalyst salts and heavy by-products.

2. Input Materials

Acetylene

Acetone

Ammonia

3. Operating Parameters

Temperature: 10-40°C (50-104°F)

Pressure: 1.97 MPa (19.4 atm)

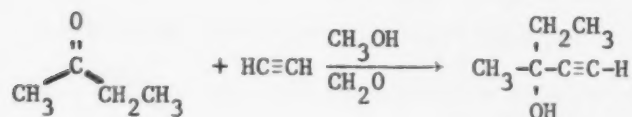
Catalyst:  $\text{NaNH}_2$  (alkali or alkaline earth oxides also acceptable)

4. Utilities - Not given
5. Waste Streams - Recycling of ammonia and excess acetylene to the reactor is a potential source of leaks to the atmosphere. Distillation to remove remaining reactants may cause atmospheric emission of solvents. The second distillation bottoms include deactivated catalyst salts and heavy by-products, which will eventually appear in waste water flow.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 208.

Ibid., Vol. 12 (1967), p. 120.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 291.

Methyl Pentynol (acetylation of 2-butanone)

1. Function - 3-Methyl-1-pentyn-3-ol is manufactured by the reaction of acetylene and 2-butanone in dimethylacetal of formaldehyde as the solvent. Sodamide, sodium or potassium hydroxide, potassium *t*-butoxide, or other alkali or alkaline earth oxides are used as condensing agents.

A typical yield for this process is 50% based on 2-butanone.

2. Input Materials

2-Butanone - 1.47 kg/kg product

Acetylene

Dimethylacetal of formaldehyde (solvent purposes only)

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst:  $\text{NaNH}_2$ , NaOH or KOH,  $\text{KOC}(\text{CH}_3)_3$ , or other alkali or alkaline earth oxides.

4. Utilities - Not given

5. Waste Streams - See description under Process No. 177.

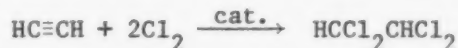
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 208.

7. References (continued)

Ibid., Vol. 12 (1967), p. 120.

1,1,2,2-Tetrachloroethane (chlorination of acetylene)

1. Function - Chlorine and acetylene are mixed independently with portions of a mixture of tetrachloroethane and antimony trichloride. These two mixtures, one containing chlorine (60-80°C) and the other acetylene (80-100°C) are then brought in contact under controlled conditions. The product 1,1,2,2-tetrachloroethane is distilled from the reaction mixture and mostly used for production of trichloroethylene. Less than 10% of trichloroethylene is derived directly from acetylene.
2. Input Materials  
Acetylene  
Chlorine
3. Operating Parameters  
Temperature - 70-80°C (158-176°F)  
Pressure - Not given
4. Utilities - Not given
5. Waste Streams - The following air emissions arise from the reflux condenser vent of the chlorination reactor.  
Ethane - 1.25 g/kg product  
Methane - 1.25 g/kg product  
Tetrachloroethane - 0.50 g/kg product  
Waste water flow may contain traces of tetrachloroethane and alkali metal compounds from washing operations as well as suspended particles of iron or other inorganic catalyst species used.

6. EPA Source Classification Code - None

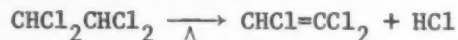
7. References

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 607, 608, 845-848.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 161-163.

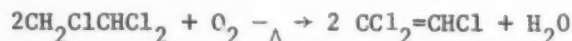
Hedley, W. H., et al., "Potential Pollutants from Petrochemical Processes," Technomic Publishing Co., Westport, Conn., 1975.



Trichloroethylene (from tetrachloroethane)

1. Function - The cracking of tetrachloroethane in the presence of a catalyst of  $\text{BaCl}_2$  on carbon is the currently preferred method of production. The reaction takes place at 250-300°C and produces a mixture of trichloroethylene and 10 percent perchloroethylene, which may be separated by distillation. After distillation from heavy ends, a small amount (20 ppm by weight) of trimethylamine or pyrrole-based compounds may be added to stabilize the product.

A small amount of trichloroethylene can be made by pyrolyzing 1,1,2-trichloroethane in the presence of air or  $\text{O}_2$ :



2. Input Materials

Tetrachloroethane

3. Operating Parameters

Temperature 250-300°C (482-572°F)

Catalyst 30 percent  $\text{BaCl}_2/\text{C}$

4. Utilities

Not given

5. Waste Streams - No specific information was available, but one would expect some HCl and various chlorohydrocarbons to be present in the gaseous and aqueous waste streams.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 115.

Faith, W. L. et al., Industrial Chemicals, 3rd Ed., John Wiley & Sons, Inc., New York, N. Y., 1965, p. 784.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 190.

Synthesis Gas (catalytic steam-hydrocarbon reforming)

1. Function - Synthesis gas is any mixture of carbon monoxide and hydrogen, in variable proportions, usually intended for conversion to ammonia, purified hydrogen, hydrocarbons, alcohols, or other organic compounds. By 1965, catalytic steam-hydrocarbon reforming used to recover hydrogen from hydrocarbon feedstocks up to and including light gasoline fractions, and producing more hydrogen, and synthesis gas mixture than any other method. In this process, gaseous hydrocarbons, such as methane are reacted with steam at 650°C to 1050°C in the presence of a suitable nickel catalyst to produce carbon oxides and hydrogen at about the same temperatures.

Important factors to be considered in the design of a steam-hydrocarbon reforming plant are:

- 1) Process Hydrocarbon. Basic requirements for a satisfactory hydrocarbon feed to a steam-reforming operation are:
  - a) Freedom from sulfur compounds. The total sulfur content should be less than 1-5 parts per million, since sulfur acts as a catalyst poison.
  - b) Absence of unsaturated hydrocarbons. These compounds tend to deposit carbon on the reforming catalyst, causing both loss of activity and physical deterioration.

c) The hydrocarbon feed should be in the vapor phase when it contacts the catalyst.

- 2) Operating Pressure. Ammonia and methanol synthesis, petroleum hydrogenation, hydrogen liquefaction, and the pressure storage of hydrogen gas all require hydrogen at elevated pressures ranging up to 100 MPa (1000 atm). Since natural gas is often available at pipeline pressures of 4 MPa (40 atm) or more, and steam may be generated efficiently at this pressure, carrying out the steam hydrocarbon reforming process at higher pressures, 1.8-3.2 MPa (18-32 atm), may result in substantial economics. Increased pressure operation also permits heat recovery from the reaction product stream at higher temperature levels, due to the higher partial pressure of the excess steam in the gas mixture.
- 3) Catalyst selection. Several commercial catalyst are available. These catalysts contain 10-35% nickel oxide mixed with refractory cement. Coimpregnation of a small amount of magnesium oxide with the nickel oxide has been found to improve the activity and stability of alumina-supported catalyst.
- 4) Tube surface temperature. The low strength of 25-20 chrome-nickel steel tubes imposes an external surface temperature limit of 930-980°C for operation at pressure greater than 1 MPa (10 atm).
- 5) Steam-hydrocarbon ratio. At atmospheric pressure, hydrocarbons may be reacted to produce hydrogen with less than 0.1% residual  $\text{CH}_4$  by using two molecules of steam per atom of

carbon in the hydrocarbon, and carrying out the reaction at temperatures above 870°C. As the operating pressure is increased, the ratio is generally increased to between 3 and 4 molecules of steam per carbon atom in the feed material.

- 6) Product gas temperature at furnace outlet. This parameter is important in determining the amount of unreacted methane remaining in the product stream and is influenced by the maximum allowable tube surface temperature, the tube diameter, and the type of furnace.
- 7) Flue gas temperature. The flue gas temperature will probably be between 900°C and 1050°C, and the flue gas will be raised to preheat the furnace feed streams and to generate steam.
- 8) Carbon monoxide removal. Substantially complete removal of CO from the product stream is required when synthesis gas is used as a source of hydrogen in the synthesis of ammonia. This processing step is accomplished by causing the raw gas mixture to react with steam via the water gas shift. The carbon dioxide formed is scrubbed with appropriate solvents.

## 2. Input Materials

Natural gas (methane) or other hydrocarbon feed

Steam - 2 to 6 kg/kg synthesis gas produced

## 3. Operating Parameters

Temperature: 650-1050°C (1202-1922°F)

3. Operating Parameters (continued)

Pressure: 1.8-3.2 MPa (17.8-31.6 atm)

Catalyst: 20-35% nickel oxide on alumina support

Residence time: 0.2-10 seconds

4. Utilities - Not given

5. Waste Streams - Condensates from catalytic reforming generally contain spent catalyst particles, hydrogen sulfide formed from residual sulfur in the feed, and ammonia formed by reaction of air with the hydrocarbons at elevated temperatures.

Regeneration of the activated carbon used for sulfur removal may lead to gaseous emissions of hydrogen sulfide and/or sulfur dioxide, if this operation is performed on site.

It is unlikely that hydrocarbons from the feed stream or carbon monoxide from the product stream would be emitted to the air.

6. EPA Source Classification Code - None

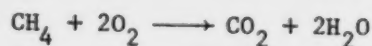
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 275,276.

Ibid., Vol. 10 (1966), p. 415-419.

U.S. Patent 3,367,882 (February 6, 1968).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition Noyes Development Corp., Park Ridge, N.J., 1969, p. 623.

Synthesis Gas (continuous, non-catalytic partial oxidation)

1. Function - Synthesis gas is a mixture of carbon monoxide and hydrogen with minor amounts of carbon dioxide and nitrogen. There are two general processes used - the steam reforming process (using a nickel catalyst) and the process described here, the non-catalytic partial oxidation process.

The partial oxidation process involves the burning of hydrocarbons in air or oxygen to produce a gas containing hydrogen and carbon monoxide with small quantities of methane,  $\text{CO}_2$  and water vapor. The use of oxygen yields a product gas of lower nitrogen content often necessary for subsequent uses of synthesis gas.

The mixture of hydrocarbon and oxygen is pre-heated to 235-650°C (455-1202°F) depending on the composition of the gas stream. It then passes to a reactor which operates at 1100-1600°C (2012-2912°F) and pressures up to 4 MPa (40 atm). The hot effluent gases are cooled in a heat exchanger, compressed and  $\text{CO}_2$  removed by absorption in water or ethanolamine solution.

The non-catalytic partial oxidation process can operate on any hydrocarbon feedstock that can be compressed or pumped. No desulfurization process is necessary since there is no catalyst involved that can be poisoned.



2. Input Materials

Natural gas (methane) -  $0.27 \text{ kg/Nm}^3$  of crude dry gas produced

( $\text{Nm}^3$  = normal cubic meters,  $0^\circ\text{C}$ , 760 mm Hg.)

Steam -  $13.40 \text{ kg/1000 Nm}^3$  of crude dry gas or  $0.05 \text{ kg/kg}$  natural gas feed (steam saturated at  $246^\circ\text{C}$  ( $470^\circ$ )).

Oxygen -  $0.26 \text{ Nm}^3/\text{Nm}^3$  of crude dry gas

3. Operating Parameters

Temperature:  $1100\text{--}1600^\circ\text{C}$  ( $2012\text{--}2912^\circ\text{F}$ )

Pressure:  $1.48\text{--}4.24 \text{ MPa}$  ( $14.6\text{--}41.8 \text{ atm}$ )

Residence time:  $<10$  seconds

4. Utilities

Boiler feed water -  $0.83 \text{ kg/Nm}^3$  crude dry gas

Cooling water -  $0.32 \text{ kg/Nm}^3$  crude dry gas

Fresh water -  $67.0 \text{ kg/1000 Nm}^3$  crude dry gas

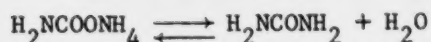
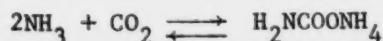
Electricity -  $16.2 \text{ kJ/Nm}^3$  crude dry gas

5. Waste Streams - The partial oxidation process produces  $0.12 \text{ kg}$  of condensate per  $\text{Nm}^3$  of crude dry product gas. Again as in catalytic reforming, it is doubtful that reactants, natural gas or oxygen, are emitted to the atmosphere during feed to the reactor. For natural gas, no soot will appear in the waste water flow. Carbon dioxide from stripping of the gas absorption system may be vented to the air.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 419-422.

Urea (once-through process)

1. Function - All commercial production of urea is based on the reaction of ammonia and carbon dioxide to form ammonium carbamate which in turn decomposes to urea and water.

The reaction is run at 175-190°C and a pressure of 16-25 MPa (160-250 atm). Under these conditions, the equilibrium urea conversions of only 40-70% can be expected. The effluent contains ammonium carbamate, urea and excess ammonia. The unreacted carbamate is decomposed to ammonia and carbon dioxide gas by heating the effluent at low pressure. The gaseous mixture is separated from the urea solution and used to produce ammonium salts by absorbing  $\text{NH}_3$ , either in sulfuric or nitric acid.  $\text{CO}_2$  is vented to the air.

Urea is recovered from the stripped effluent solution either by evaporation or crystallization. Biuret, a condensation product of urea forms under conditions of high temperature and reduced pressure, and must be minimized for certain industrial uses of urea. Urea, produced by crystallization, contains only 0.2-0.3% of biuret. Product produced by evaporation contains a much higher biuret content.

Urea is marketed in the form of small spherical particles called prills. These are formed by spraying molten urea, at the top of a 50M cylindrical column into a counter current stream of air.

The molten urea freezes into spheres which are collected at the column bottom. The biuret content in this material is 0.6-1.5%.

2. Input Material

Ammonia - 1.87-1.77 kg/kg urea produced

Carbon dioxide (from synthesis gas) - 0.91-1.47 kg/kg urea produced

3. Operating Parameters

Temperature: 175-190°C (347-374°F)

Pressure: 16-25 Mpa (160-250 atm)

4. Utilities - Not given

5. Waste Streams - The high vapor pressure of ammonium carbamate at elevated temperatures, may result in atmospheric emissions of that species from the urea synthesis reactor. Some ammonia may be emitted during solidification of urea by evaporation as a by-product of biuret formation. The prilling tower may be a source of particulates as well.

6. EPA Source Classification Code - None

7. References

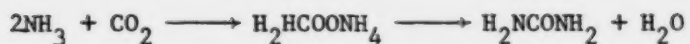
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 9," "Chemical Engineering," August 5, 1974, p. 97.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 21 (1970), p. 43-45.

U.S. Patent 3,072,721 (January 8, 1963).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 690.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 857.

Urea (recycle processes)

1. Function - The urea synthetic processes can be divided into two general classes, the "once through process," described as a separate process, and the "recycle process." The recycle process is one in which unreacted carbon dioxide and ammonia either in the free form or combined as ammonium carbamate, are returned to the system for further conversion to urea.

There are many versions of the recycle process which differ basically in the manner in which the  $\text{CO}_2$  and  $\text{NH}_3$  are recovered and returned to the reactor. There may be two or three stages of carbamate decomposition each succeeding stage operated at a lower pressure and temperature.

Ammonia and carbon dioxide gases are liquified (compressed) and charged to a steam-heated, silver lined autoclave which is maintained at  $175 - 200^\circ\text{C}$  and  $170 - 408$  atm. The ammonia and carbon dioxide are converted to ammonium carbamate which decomposes to urea. The product mix consists of 35% urea, 15% ammonia, 21% ammonium carbamate and 14% water. The product is fed to a carbamate decomposer at a pressure reduced from that of the

reactor. Here carbamate decomposes into  $\text{NH}_3$  and  $\text{CO}_2$ , the gas is recovered, cooled, and recycled to be again converted to ammonium carbamate. The effluent solution is passed to a second carbamate decomposer which is operated at a lower temperature and pressure. Additional carbamate decomposition occurs here, the gases being collected, cooled and recycled as before and the effluent passing to a third carbamate decomposer which again operates at a lower temperature and pressure. Effluent from the third stage passes to a crystallizer where urea crystals are recovered.

2. Input Materials - Basis - 1 metric ton urea

Ammonia - 2000 kg

Carbon dioxide - 900 kg

3. Operating Parameters

Temperature: Reactor - 175-200°C (347-392°F)

1st Decomposition stage - 150°C (302°F)

2nd Decomposition stage - 130°C (266°F)

3rd Decomposition stage - 120°C (248°C)

Pressure: Reactor - 17.2-41.4 MPa (170-408 atm)

1st Decomposition stage - 1.8 MPa (18 atm)

2nd Decomposition stage - 0.4 MPa (4 atm)

3rd Decomposition stage - 100 kPa (1 atm)

4. Utilities - Data for Stamicarbon recycle urea plant producing fertilizer grade plus, biuret content = 0.2-0.25%

Basis - 1000 kg urea

Steam - (2.6 MPa) - 1100 kg

Cooling water - 65 m<sup>3</sup>

Power - 504 MJ (140 kw)

5. Waste Streams - Loss of  $\text{NH}_3$  to the atmosphere during staged decomposition and absorption are possible emissions.  $\text{CO}_2$  may also be emitted in the various stripping operations.

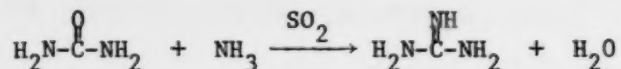
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 21, (1970), p. 45-51.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November, 1975, p. 210-11.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., (1975), p. 854-857.

Guanidine (from urea)

1. Function - Guanidine may be manufactured by the reaction of urea with ammonia and sulfur dioxide. Urea, liquid sulfur dioxide, and ammonia (in molar ratio 1:3:7) are heated to 275°C under pressure for approximately 30 minutes. Guanidine (as the sulfate) is obtained in 80% yield. The reaction product is dissolved in water and filtered to remove sulfur. The solution is concentrated and treated with nitric acid to form guanidine nitrate. Guanidine is usually marketed as the nitrate or the chloride.
2. Input Materials  
Urea  
SO<sub>2</sub>  
NH<sub>3</sub>
3. Operating Parameters  
Temperature: 245-275°C  
Pressure: 20.2 MPa (200 atm)  
Time: 30 minutes
4. Utilities - Not given
5. Waste Streams  
Air - NH<sub>3</sub> and SO<sub>2</sub>  
Water - Traces of reactants and products  
Solid waste - Sulfur

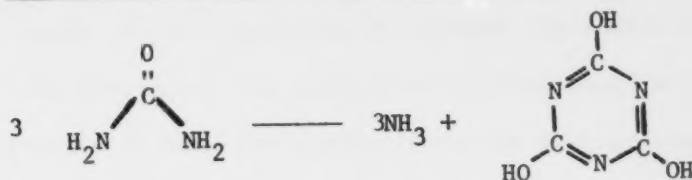


6. EPA Source Classification Code - None

7. References

Astle, M. J., Industrial Organic Nitrogen Compounds, Reinhold Publishing Corp., New York, N.Y., 1961, p. 301.

Boivin, J. L., "Canadian J. Chem," 34, 827 (1966).

Cyanuric Acid (thermal decomposition of urea)

1. Function - Heating urea for several hours at 200-300°C results in deamination and the formation of cyanuric acid.

For temperatures much above 300°C, the yield of product decreases due to depolymerization.

Conversion to cyanuric acid occurs in stages. Initially, urea melts at 133°C to form a free-flowing liquid. As heating continues, the reaction mass thickens and finally solidifies, although at this point significant amounts of urea, biuret,  $\text{H}_2\text{NCONHCONH}_2$ , and triuret,  $\text{H}_2\text{NCONHCONHCONH}_2$ , are present. Additional heating converts these to cyanuric acid. The product of pyrolysis strongly adheres to the walls of the reactor and is removed with great difficulty. Several methods have been patented to overcome such problems.

- (1) conducting pyrolysis on a molten tin or lead bath
- (2) conducting pyrolysis in a fluidized bed
- (3) recycling 60-90% of crude cyanuric acid into a rotating kiln to mix with urea prior to pyrolysis
- (4) running the reaction in certain high-boiling organic solvents
- (5) heating urea at 165°C for about two hours to get a liquid mixture consisting of urea, biuret, triuret, and cyanuric acid, followed by further pyrolysis for ten minutes at 240-270°C on a rotating heated drum.

Crude cyanuric acid produced by pyrolysis may be contaminated with as much as 20-30% impurities consisting mostly of ammelide and ammeline with minor amounts of melamine, biuret, urea, and triuret. Two general purification techniques will be described.

Cyanuric acid may be dissolved in ammonium hydroxide solution or hot dimethylformamide solution. Filtering the mixture will remove most of the impurities. The product may be precipitated from the ammonium solution by acidification with mineral acid or from the DMF solution by cooling and adding carbon tetrachloride.

Crude cyanuric acid may also be purified by heating it in 10-20% sulfuric, nitric, or hydrochloric acid for several hours. This process hydrolyzes most of the ammelide, ammeline, and melamine to cyanuric acid. The slurry is then filtered or centrifuged and the solids collected are washed with water to remove residual traces of the acid used earlier. Cyanuric acid can be dried in any conventional dryer, up to a maximum temperature of 200°C, to give a product of at least 98% purity.

2. Input Materials - urea

3. Operating Parameters

Temperature: 200-300°C (392-572°F)

Pressure: 101 kPa (1 atm)

4. Utilities

Not given

5. Waste Streams - Ammonia produced during decomposition of urea is probably emitted to the atmosphere. All other compounds (cyanuric acid, biuret, triuret, ammeline, ammelide, melamine) are solids at ordinary temperatures, and although they occur in the liquid phase

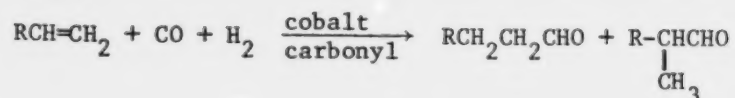
during reaction, the vapor pressures are probably too low to lead to any pollution problems.

Purification is a source of additional emissions. The precipitation method will lead to the presence of the various solvents or acid in wastewater. The acid-digestion process waste is probably neutralized, leading to spent caustic in wastewater. Drying operations should not pose any significant pollution problems.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 20 (1969), p. 667, 668.

Oxo Aldehydes (oxo process)

1. Function - The oxo process consists of the hydroformylation of olefins to give aldehydes (and ultimately alcohols) of the next higher homologue. The olefin feed is usually mixed with a slurry of the cobalt catalyst (usually in the form of cobalt naphthenate) and introduced to the converter together with the synthesis gas. The reaction takes place in the liquid phase at 130-175°C and 200-300 atm.

The liquid reaction products go to a phase separator then to a cobalt removal system (decobalter). The cobalt catalyst is regenerated and recycled. The crude aldehydes are refined by distillation.

2. Input Materials

Olefin - (90%)

Synthesis gas - [CO (98-99%) + H<sub>2</sub> (98-99%)]

Co catalyst

Steam

CO<sub>2</sub>

3. Operating Parameters

Temperature - 130-175°C

Pressure - 200-300 atm. (20.2-30.4 MPa)

4. Utilities - Not given

5. Waste Streams -

Air - Emissions stemming from the formation of by-products such as paraffins from hydrogenation of starting olefin; olefin feed and synthesis gas leaks.

Water or solid wastes - Wastes resulting from the high-boiling oxygenated compounds formed from condensation of aldehydes and alcohols.

6. EPA Source Classification Code - None

7. References

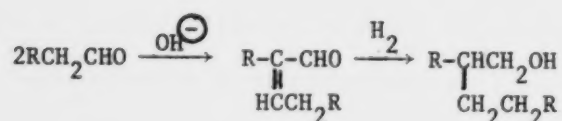
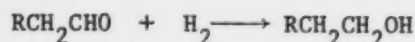
Sittig, M., "Oxo Products From Olefins," in Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, New Jersey, 1974, p. 175.

US Petrochemicals, Technologies, Markets, and Economics, Brownstein, A. M., Ed., The Petroleum Publishing Company, Tulsa, Oklahoma, 1972, pp. 92-93.

Hahn, A.V., The Petrochemical Industry: Markets and Economics, McGraw-Hill Book Company, New York, 1970, pp. 104-105.

"Oxo Process" in Chemical and Process Technology Encyclopedia, Considine, D. M., Ed-in-Chief, McGraw-Hill Book Company, New York, 1974, pp. 793-794.

Haberstroh, W. H. and Collins, E.M., "Oxo Chemicals," in Riegels' Handbook of Industrial Chemistry, 7th edition, Kent, J. A., Ed., Van Nostrand Reinhold Company, New York, 1974, pp. 774-775.

Oxo Alcohols

1. Function - Alcohols are usually the ultimate product of the oxo-process (Process No. 187). The alcohols are obtained by: (a) direct reduction of the aldehyde; (b) dimerization of the aldehyde by aldol condensation followed by reduction to the alcohol; or (c) single stage low pressure oxo process. In (a), the aldehyde from the decobalter is hydrogenated at elevated temperature and pressure to give the alcohol. In (b) the aldehyde from the decobalter is fed into a condensation reactor where the aldolization is carried out in the presence of caustic. Water is continually removed from the condensation reaction to drive it to completion. The resulting aldehyde is then hydrogenated to the alcohol.

An alternate route was recently introduced. Olefin feed and recycled catalyst are charged to the first of a series of packed reactors at controlled rates. Synthesis gas ( $\text{H}_2:\text{CO} = 2.5:1$ ) is fed separately to each reactor. The overhead stream from the final reactor is sent directly to the recovery column. The bottoms from the recovery column contain catalyst complex in a mixture of alcohols and heavy ends. This stream is recycled to the first reactor with periodical purging to remove built-up heavy ends.



This reaction is carried out in alkaline medium with a specially promoted cobalt carbonyl catalyst. The dimer and monomer alcohols are obtained directly from the reaction mixture.

2. Input Materials

Aldehyde

Hydrogen

Phosphine-promoted cobalt carbonyl

Nickel catalyst

Zinc compound

Olefin

Synthesis gas

Caustic

3. Operating Parameters

a. Temperature - 150-200°C (302-392°F)

Pressure - (1500-3000 psi) 10.3-20.6 MPa (102-204 atm)

b. Temperature - 90-230°C (194-446°F)

Pressure - < than (a)

c. Temperature - Not given

Pressure - < 30 atm. 3.04 KPa (30 atm)

4. Utilities - Not given

5. Waste Stream - Air - hydrocarbons from leaks. Water - High boiling oxygenated intermediates, byproducts, and heavy ends. A typical plant survey showed: Flow - 1.59 m<sup>3</sup>/454 kg, COD - 1.21 kg/m<sup>3</sup> and 1.93 kg/454 kg, BOD<sub>5</sub> - 0.9 kg/m<sup>3</sup>, 1.43 kg/454 kg, and TOC - 0.549 kg/m<sup>3</sup>, .87 kg/454 kg.

6. EPA Source Classification Code - None

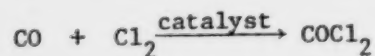
7. References

Sittig, M., "Oxo Products from Olefins," in "Pollution Control in the Organic Chemical Industry," Noyes Data Corporation, Park Ridge, New Jersey, 1974, pp. 175-177.

Long, F.W., "Technology and Markets of Petrochemicals Derived from Synthesis Gas," in "US Petrochemicals: Technologies, Markets, and Economics," Brownstein, A. M., Ed., The Petroleum Publishing Company, Tulsa, Oklahoma, 1972, pp. 92-94.

Waddams, A.L., Chemicals From Petroleum, 3rd Edition, John Murray Ltd., London (1973), p. 204-206.

Phosgene (catalytic reaction of carbon monoxide  
and chlorine)



1. Function - Phosgene is manufactured by reacting chlorine gas and carbon monoxide in the presence of activated carbon. Dry carbon monoxide of the highest possible purity is metered and mixed in a reactor with dry and pure chlorine at a temperature of 200°C and 2 to 4 psig over gas-mask grade activated charcoal.

The hot effluent gases leaving the reactor are led to a condenser, where liquid phosgene is removed. The non-condensable gases are scrubbed with a hydrocarbon solvent to remove entrained phosgene. Nearly all phosgene is used at the point of manufacture, mostly in the manufacture of isocyanates for polyurethane resins.

2. Input Materials

Carbon monoxide - 230 m<sup>3</sup>/metric ton product

Chlorine - 720 kg/metric ton product

3. Operating Parameters

Temperature - 200°C (392°F)

Pressure - 13.8-27.6 kPa (0.14-0.27 atm)

Catalyst - activated charcoal 15 kg/metric ton product

4. Utilities - Not given

5. Waste Streams - Any phosgene waste (not feasible to recycle) is scrubbed with sodium hydroxide.

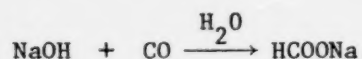
6. EPA Source Classification Code - None

7. References

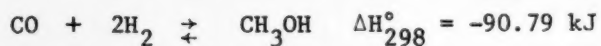
Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N. Y., 1975, p. 624-627.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Supplemental Volume (1971) p. 677-681.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 108-109.

Sodium Formate (carbon monoxide and sodium hydroxide)

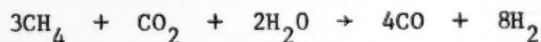
1. Function - Clean and compressed synthesis gas (source of carbon monoxide) is introduced countercurrently into a 25-30% sodium hydroxide solution at 160-200°C to give sodium formate. Sodium formate crystals are obtained by drying the reaction product.
2. Input Materials  
Synthesis gas (source of carbon monoxide)  
Sodium hydroxide
3. Operating Parameters  
Temperature - 160-200°C (320-392°F)  
Pressure - 140-170 kPa (1.38-1.68 atm)
4. Utilities - Not given
5. Waste Streams - Waste water is likely to contain sodium hydroxide.  
Atmospheric emissions of carbon monoxide and hydrogen are possible.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 101.  
  
Gmelins Handbuck der Anorganische Chemie, System-Nummer 21, 8 Auflage  
Erganzungsband, Lieferung 4, Verlag Chemie, 1967, p. 1398.

Methanol (high-pressure catalytic synthesis)

1. Function - Methanol synthesis from CO and H<sub>2</sub> is favored by high pressures and low temperatures. The temperature and pressure applied in commercial processes is dependent on: composition of synthesis gas utilized, and rate of reaction at a given temperature and pressure in the presence of a given catalyst.

The main source of synthesis gas at present is the steam reforming of natural gas. Very exact process control is needed to maintain a desired carbon monoxide - hydrogen ratio.

The reforming of natural gas by steam may be represented by the following equation



The synthesis gas is compressed to remove water and entrained oil. The compressed mixture of gases is passed through a catalytic converter. Commercial processes usually operate at temperatures ranging from 350°C to 400°C and at pressures in the 19.6-29.4 MPa range. Catalyst used in the high-pressure synthesis consists mainly of mixtures of chromium oxide and zinc oxide. Close control of operating parameters to suppress side reactions is of utmost importance. The mixture of gases from the converter pass through a condenser and then through a separator. The crude methanol condensate is subsequently purified in a two-step distillation. By-products are mixed alcohols (19.3 g/kg methanol) and dimethyl ether (20.4 g/kg methanol).

Methanol plant equipment must be resistant to carbon monoxide at high temperatures and pressures.

Copper-based catalyst have been known to increase the rate of the reaction for the formation of methanol from synthesis gas, but were readily inactivated by sulfur impurities present in synthesis gas. Improved methods of removing sulfur from synthesis gas and newly-perfected copper-zinc catalyst has led to a new low-pressure process for the manufacture of methanol from synthesis gas. The new low-pressure process developed by Imperial Chemical Industries Limited of United Kingdom operates at pressures nearly half of those utilized in usual processes. Some methanol was also produced in the liquid phase oxidation of butane--rich hydrocarbon gas (Process No. 227). However, this process has not been in commercial use since 1973.

## 2. Input Materials

- 1) Synthesis gas - produced by steam reforming of 0.829 kg natural gas per kg  $\text{CH}_3\text{OH}$ .
  - a) 5.8-7.3 kg CO/kg  $\text{CH}_3\text{OH}$  (based on 12-15% conversion of CO)
  - b) .87-1.31 kg  $\text{H}_2$ /kg  $\text{CH}_3\text{OH}$  (based on  $\text{H}_2$ :CO molar ratio of 2.1-2.5)
- 2) Carbon dioxide - recovered from reformer flue gases.

## 3. Operating Parameters

Temperature: 350-400°C (662-752°F)

Pressure: 20-30 MPa (200-300 atm.)

Catalyst:  $\text{Cr}_2\text{O}_3$  + ZnO



4. Utilities - Basis - 10.5 kg/sec (1000 tons/day) capacity

Cooling water -  $2.089 \text{ m}^3/\text{sec}$  (33,110 gal/min)

Makeup water -  $70.0 \text{ dm}^3/\text{sec}$  (1,100 gal/min)

Power - 11.0 GJ (3.06 Mw)

Natural gas -  $13.49 \text{ Nm}^3/\text{sec}$  (1.715 M scfh)

5. Waste Streams - Major waste water streams are from slab and vessel washdowns together with bottoms from the methanol purification process. This amounts to  $0.4\text{--}2.1 \text{ m}^3/\text{kg}$  of product (100-500 gal/ton) and contains some oils, methanol, and higher-boiling organic compounds to the extent of about  $0.2\text{--}0.5 \text{ kg}/1000 \text{ m}^3$ .

|                  | <u>Plant 1</u>                   | <u>Plant 2</u>                    |
|------------------|----------------------------------|-----------------------------------|
| Flow             | $0.492 \text{ m}^3/\text{kg}$    | $0.352 \text{ m}^3/\text{kg}$     |
| COD              | 320 mg/l<br>$0.16 \text{ g/kg}$  | 4,930 mg/l<br>$1.74 \text{ g/kg}$ |
| BOD <sub>5</sub> | 119 mg/l<br>$0.059 \text{ g/kg}$ | 2,620 mg/l<br>$0.92 \text{ g/kg}$ |
| TOC              | 107 mg/l<br>$0.053 \text{ g/kg}$ | 583 mg/l<br>$0.21 \text{ g/kg}$   |

6. EPA Source Classification Code - None

7. References

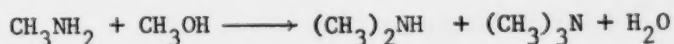
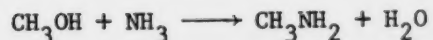
Chemistry In The Economy - American Chemical Society Study, p. 31, 1973.

Hedley, William H., et al., Potential Pollutants From Petrochemical Processes, Technomic Publishing Co., Westport, Conn., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 375-378.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 158-159.

Methylamines  
(vapor-phase ammonolysis of methanol)



1. Function - The manufacture of methylamines is a classic example of vapor phase ammonolysis of alcohols. Methylamine, with smaller quantities of both dimethylamine and trimethylamine, is produced by passing methanol and ammonia, in a 1:5 volume ratio and preheated to 350°C, over a dehydrating catalyst at space velocities of 0.75 - 1.5 and a catalyst temperature of 450°C. The process is usually carried out under atmospheric pressure, but it can be performed under pressures in excess of 690 kPa (6.8 atm) with direct fractionation of the products at these conditions. Catalysts commonly used are alumina ( $\text{Al}_2\text{O}_3$ ), aluminum silicate, aluminum phosphate, and diammonium phosphate. Conversion of the ammonia is 13.5% to primary, 7.5% to secondary, and 10.5% to tertiary amine.

Part of the exothermic heat of reaction may be used in the feed preheater.

Since exclusive production of one of the amines is difficult and frequently uneconomical, much of the process development concerning methanol ammonolysis has dealt with the problem of satisfactory separation of the three co-products. Recycling of the less desirable amines to increase the yield of the desired product is generally effective even if the secondary or tertiary

amine is preferred. If dimethylamine is desired, the other two amines may be recycled without separation from each other. Separation or fractionation of the product stream is rather difficult because the boiling points of the methylamines all lie in a temperature range of only about 10°C.

The crude product can be separated by a series of four column distillations. The first column is maintained at a suitable temperature and pressure so that the trimethylamine-ammonia azeotrope to be recycled is recovered overhead, the recyclable ammonia from the upper middle of the column, and a mixture of mono-, di-, and some tri-methylamine as bottoms. The mixture goes to the trimethylamine (TMA) column where water is added for extractive distillation and pure TMA is collected overhead and sent to storage or recycle. The bottoms from this operation are sent to the mono-methylamine (MMA) column where pure MMA is removed overhead. Finally, the MMA column bottoms are sent to a fourth column where pure dimethylamine goes overhead with water drained from the bottom to waste.

Procedures have also been devised for separating the methylamines from mixtures by extractive distillation. Mono-methylamine is separated from the other two by absorbing the vapors in a liquid in which it has the lowest solubility of the three, such as dimethylaniline, 1,2,3,4-tetrahydronaphthalene, or dimethylcyclohexylamine. Fractional distillation of this solution yields MMA overhead. Dimethylamine is separated from MMA and TMA by subjecting the mixture to extractive distillation using aniline, morpholine,

dimethylformamide, or diethanolamine, in which DMA is the most soluble. The diethylamine is recovered by flashing from the solvent. By using solvents in which TMA is the least soluble, the member of the series may be distilled from mixture.

2. Input Materials - kg/kg of desired methylamine produced

Methanol (industry average factor/highest value)

a) MMA; 1.05/1.2

b) DMA: 1.45/1.6

c) TMA: 1.65/1.8

Ammonia (assuming 97% yield)

a) MMA; 0.565

b) OMA: 0.389

c) TMA: 0.297

3. Operating Parameters

Temperature: 450°C (842°F)

Pressure: 690 kPa (6.8 atm)

Catalyst:  $\text{Al}_2\text{O}_3$

4. Utilities - basis: 45.4 kg (100 lb) of anhydrous product

Steam - 590 kg (1300 lbs)

Water - 13.2 m<sup>3</sup> (3500 gallons)

Electricity - 32.4 MJ (9 kWh)

5. Waste Streams - The staged distillation process is the source of most of the pollutants in methylamine manufacture. The bottoms from the DMA column, the last in the series of four, are drained to wastewater and will contain some of all three methylamines in solution.

Two examples of the wastewater are:

|                  | #1         | #2         |
|------------------|------------|------------|
| Flow             | 3.58 l/kg  | 3.57 l/kg  |
| COD              | 22.56 g/kg | 4.21 g/kg  |
|                  | 6.303 g/l  | 1.178 g/l  |
| BOD <sub>5</sub> | 0.35 g/kg  | 0.62 g/kg  |
|                  | 99 mg/l    | 1.74 mg/l  |
| TOC              | 41.65 g/kg | 13.63 g/kg |
|                  | 11.634 g/l | 3.808 g/l  |

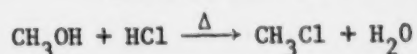
Atmospheric emissions of hydrogen and carbon monoxide and of methylamines will arise from crude product storage and final storage, respectively.

6. EPA Source Classification Code - None

7. References

"1973 Petrochemical Handbook," "Hydrocarbon Processing,"  
November, 1973, p. 150.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Inter-  
science Publishers, New York, N.Y., Vol. 2 (1963), p. 122.

Methyl Chloride1. Function

Methyl chloride is produced by the action of hydrogen chloride on methanol, with the aid of a catalyst, in the vapor phase. Vapors of methanol and hydrogen chloride are continuously mixed in approximately equimolecular ratios and passed through a preheater maintained at about 180°C.

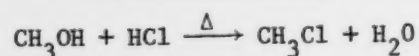
The gas mixture is then passed at substantially atmospheric pressure through a converter at a temperature of 340°C to 350°C. The converter is packed with previously ignited alumina gel of 8 to 12 mesh size or a similar catalyst, such as zinc chloride on pumice, cuprous chloride, or activated carbon. Space velocities of about 7.79 m<sup>3</sup> (275 cubic feet) per hour per 28 dm<sup>3</sup> (cubic foot) of gross catalyst volume are generally used (based on gas volumes at STP).

The effluent gases from the reactor are scrubbed with water to remove excess HCl, followed by an alkali wash, and a sulfuric acid wash (to dry the product). Crude methyl chloride is distilled under pressure at -24°C to yield pure methyl chloride.

2. Input Materials - Basis - 1 metric ton methyl chloride

|                                              |                    |
|----------------------------------------------|--------------------|
| Methanol - 360 kg/Mg (720 lb/ton) of product | 700 kg (1,543 lbs) |
| HCl - 1587 kg/Mg (3,174 lb/ton) of product   | 800 kg (1,769 lbs) |
| Sulfuric Acid                                |                    |
| Caustic Soda                                 |                    |



Methyl Chloride1. Function

Methyl chloride is produced by the action of hydrogen chloride on methanol, with the aid of a catalyst, in the vapor phase. Vapors of methanol and hydrogen chloride are continuously mixed in approximately equimolecular ratios and passed through a preheater maintained at about 180°C.

The gas mixture is then passed at substantially atmospheric pressure through a converter at a temperature of 340°C to 350°C. The converter is packed with previously ignited alumina gel of 8 to 12 mesh size or a similar catalyst, such as zinc chloride on pumice, cuprous chloride, or activated carbon. Space velocities of about 7.79 m<sup>3</sup> (275 cubic feet) per hour per 28 dm<sup>3</sup> (cubic foot) of gross catalyst volume are generally used (based on gas volumes at STP).

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| Methanol - 360 kg/Mg (720 lb/ton) of product | 700 kg (1,543 lbs) |
| HCl - 1587 kg/Mg (3,174 lb/ton) of product   | 800 kg (1,769 lbs) |
| Sulfuric Acid                                |                    |
| Caustic Soda                                 |                    |



3. Operating Parameters

Preheater temperatures: 180 - 200°C (356 - 392°F)

Converter temperatures: 350°C (662°F)

Pressure: atmospheric

Space velocity: 275 m<sup>3</sup>/hr

Catalyst: Alumina gel. Cuprous chloride on activated carbon or pumice. Zinc chloride on activated carbon or pumice. Phosphoric acid on activated carbon.

4. Utilities

Not given

5. Waste Streams - Waste water from scrubbers contains traces of HCl, some alkali and sulfuric acid.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1967), p. 106,107.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 533.

Methyl Acetate (by esterification)

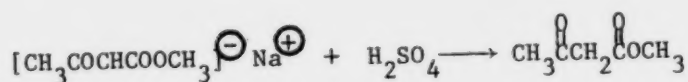
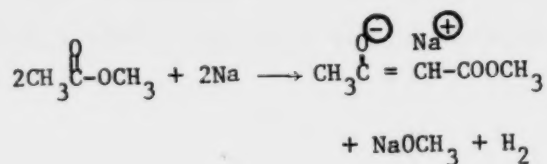
1. Function - In a general procedure for manufacturing methyl esters the aliphatic carboxylic acid (in this case acetic acid) is reacted with an excess of methanol in ethylene dichloride as solvent. Sulfuric acid is used as catalyst for the reaction. The mixture is heated to reflux from 6 to 15 hours. After cooling the reaction product is washed with water, sodium bicarbonate, water and dried by conventional methods. The ethylene dichloride is removed by distillation. The crude ester is then distilled.
2. Input Materials  
Methanol  
Acetic acid  
 $\text{H}_2\text{SO}_4$   
Ethylene dichloride
3. Operating Parameters  
Temperature: Reflux  
Pressure: 101 kPa (1 atm)  
Catalyst:  $\text{H}_2\text{SO}_4$   
Time: 6-15 hrs
4. Utilities - Not given
5. Waste Streams - Waste water may contain dilute solutions of salts of acids, traces of methanol, methyl acetate, and other organic by-products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 8 (1965), p. 350.

U.S. Patent 2,787,636 (April 2, 1957).

Methyl Acetoacetate (action of metallic sodium on methyl acetate)

1. Function - Methyl acetoacetate is prepared by the reaction of high-purity methyl acetate with metallic sodium in absolute methanol. The sodium derivative is then neutralized with sulfuric acid to give the product.

The crude ester is separated and purified by vacuum distillation.

2. Input Materials

Methyl Acetate

Metallic sodium

Absolute Methanol

Sulfuric acid

3. Operating Parameters - Not given

4. Utilities - Not given

5. Waste Streams - Hydrogen, a by-product; may be released into the atmosphere. Wastewaters may contain sodium hydroxide and sodium bisulfate as well as traces of methanol and sulfuric acid.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 154-155.

Dimethyl Ether

1. Function - Dimethyl ether is produced from methanol using sulfuric acid as the dehydration catalyst or by passage over catalyst such as alumina.

A mixture of methyl alcohol and concentrated sulfuric acid is slowly heated to 110-140°C. In this temperature range the reaction is initiated. An azeotrope of ether-water-alcohol distills from the reactor at 110°C and passes to a scrubber. The vapors pass countercurrently to a slow moving stream of dilute sodium hydroxide. The vapors from the top of the scrubber run to a continuous fractionation column where separation takes place. Alcohol and sulfuric acid are recycled.

2. Input Material

Methanol

Sulfuric Acid

3. Operating Parameters

Temperature: 140°C (284°F)

Pressure: 101 kPa (1 atm)

Catalyst:  $\text{H}_2\text{SO}_4$

4. Utilities - Not given

5. Waste Streams - Waste water may contain traces of ether, aldehydes, and peroxides as well as sodium sulfate from neutralization.

Some reduction of sulfuric acid occurs with evolution of sulfur dioxide. Tarry materials are disposed as solid waste.

6. EPA Source Classification Code - None

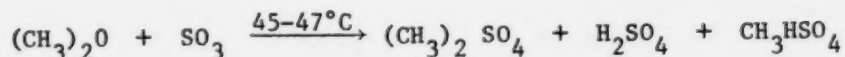
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 8 (1965), p. 474-476.

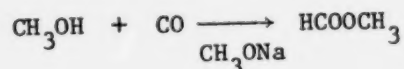
Houben-Weyl, Methoden der Organischen Chemie, Vierte Auflage, George Thieme Verlag, Stuttgart, Bd. 6, T. 3, (1965), p. 13.

Faith, W. L., et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N. Y., 1965, p. 335-336.



Dimethyl Sulfate

1. Function - Dimethyl sulfate is obtained in a continuous process utilizing dimethyl ether and liquid sulfur trioxide as the input materials. Gaseous dimethyl ether is bubbled into the bottom of an aluminum tower filled with dimethyl sulfate. Liquid sulfur trioxide is introduced at the top of the tower. The mildly exothermic reaction is controlled at 45-47°C. The reaction product (96-97% dimethyl sulfate) is continuously withdrawn and purified by vacuum distillation over sodium sulfate.
2. Input Materials  
Dimethyl ether (74.3 kg/hr)  
Sulfur trioxide (129.1 kg/hr)
3. Operating Parameters  
Temperature 45-47°C (113-117°F)
4. Utilities  
Not given
5. Waste Streams - Possible gaseous emissions of  $\text{SO}_x$ . The bottoms from distillation contain sulfuric acid and methyl hydrogen sulfate.
6. EPA Source Classification Code - None
7. Reference  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 492.

Methyl Formate

1. Function - Methyl formate may be prepared industrially by the reaction of methanol with carbon monoxide (from synthesis gas) in the presence of metal alkoxides. Hydrogen reacts with excess carbon monoxide to form methanol which is re-cycled.
2. Input Materials  
Methanol  
Synthesis gas ( $\text{CO} + \text{H}_2$ )  
 $\text{CH}_3\text{ONa}$  ( $\text{CH}_3\text{OH} + \text{Na}$ )
3. Operating Parameters  
Temperature -  $80^\circ\text{C}$  ( $176^\circ\text{F}$ )  
Pressure - 2.96 kPa (300 atm)  
Residence time - 350 sec.
4. Utilities - Not given
5. Waste Streams - By product of the reaction, e.g., dimethyl ether. Also some high-boiling tars are formed.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 4 (1965), p. 434-435.  
Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Wiley and Sons, New York, N.Y., 1973, p. 204.

Formamide

1. Function - Formamide can be manufactured by the reaction of ammonia with methyl formate. Formamide was used as a source of HCN. This HCN process is considered obsolete now.
2. Input Materials  
Methyl formate  
Ammonia
3. Operating Parameters  
Temperature - 40°C (104°F)  
Pressure - 140 kPa (200 psi) (1.38 atm)
4. Utilities - Not given
5. Waste Streams - Gaseous emission of methanol, ammonia and methyl formate are possible.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 576.  
Ibid., Vol. 10 (1966) p. 105.  
Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 484.

N,N-Dimethylformamide

1. Function - N,N-Dimethylformamide (DMF) is derived from the reaction of methyl formate with dimethylamine. The reaction product is separated from methanol and unconverted reactants by distillation.

2. Input Materials

Methyl formate

Dimethylamine

3. Operating Parameters

Not given

4. Utilities - Not given

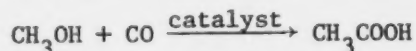
5. Waste Streams - Possible atmospheric emissions are - methanol, methyl formate and dimethylamine.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 109.

Astle, M.J., Industrial Organic Nitrogen Compounds - ACS Monograph No. 150, Reinhold Publishing Corp., 1961 p. 74.

Acetic Acid (from methanol by carbonylation)

1. Function - Methanol is carbonylated with carbon monoxide to produce acetic acid. Various types of catalysts have been proposed for the carbonylation of methanol. The catalyst most widely employed consists of two main components: 1) a carbonyl-forming metal from the iron sub-group (iron, cobalt, or nickel), and 2) either  $\text{BF}_3$  or  $\text{H}_3\text{PO}_4$ .

2. Input Materials - Basis - 1 metric ton acetic acid

Methanol - 610 kg/Mg acetic acid                      553 kg (1,175 lbs/ton)

Carbon monoxide - 787 kg/Mg acetic acid    467 kg (1,030 lbs/ton)

3. Operating Parameters

Temperature: 200 - 300°C (392-572°F)

Pressure: 20 to 70 MPa (197-691 atm)

Flow rates: not given → reaction time 1 - 3 minutes; vapor or liquid phase

Size of Equipment: not given - tubular reactor type

Types of catalysts: Fe, Co, or Ni acetate +  $\text{BF}_3$  or  $\text{H}_3\text{PO}_4$ . Monsanto has a new catalyst (a soluble rhodium-metal-carbonyl complex activated with an iodide promoter) which permits this reaction to proceed at pressures as low as 210 kPa (2 atm) and allows use of synthesis gas as a CO source.

4. Utilities - Basis: 45.5 Gg/yr (100 M lb/yr) capacity:

Water

Cooling - 287 dm<sup>3</sup>/s (4,560 gpm)

Makeup -  $6.1 \text{ dm}^3/\text{s}$  (97 gpm)

Power - 6.98 GJ (1940 kWh)

Steam - 15.8 Mg/hr (34,800 lb/hr)

5. Waste Streams - Reaction section - off-gas scrubber vent (air)

Hydrogen - 5.5 kg/Mg acetic acid

Carbon monoxide - 204 kg/Mg acetic acid

Methane - 12.7 kg/Mg acetic acid

Methanol - 14.9 kg/Mg acetic acid

Light ends - 2.2 kg/Mg acetic acid

About 40 kg (~88 pounds) of organics (50% propionic acid and 50% higher organics) are produced in the liquid waste stream per Mg (tonne) of acetic acid produced. The waste stream amounts to about  $200 \text{ dm}^3/\text{Mg}$  (50 gallons per ton) of product including drains.

6. EPA Source Classification Code - None

7. References

Yakaoka, S., "Acetic Acid," Report No. 37, Stanford Research Institute, Menlo Park, California, March, 1968.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollutational Problems Associated with Petrochemical Wastes," for FWPCA, Contract No. 14-12-461, February, 1970.

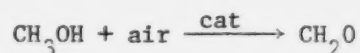
Austin, G. T., "Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 128,129.

Sittig, M., Acetic Acid and Anhydride, Noyes Development Corporation, Pearl River, N. Y., 1965, p. 24-29.

7. References (continued)

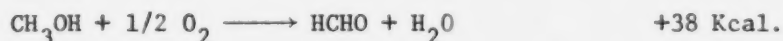
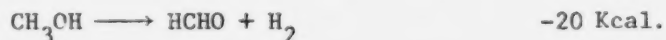
Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 10,11.



Formaldehyde(catalytic air oxidation of methanol)

1. Function - All formaldehyde in the United States is produced from methanol by either vapor-phase catalytic oxidation or by a combination oxidation-dehydrogenation process. The product is usually marketed as formalin -- a 37% solution stabilized with 9% methanol.

The catalytic conversion of methanol to formaldehyde involves the reaction of a mixture of methanol vapors and air over a stationary catalyst at approximately atmospheric pressure. Because methanol and air form explosive mixtures in the range 6-37% by volume of methanol in air at 60°C, the commercial processes operate either at methanol concentrations of nearly 50% or 5-10% by volume of methanol in air. In the catalytic conversion of methanol to formaldehyde, using silver catalyst, dehydrogenation and oxidation of methanol may occur simultaneously.



Clean air is heated and mixed with methanol vapors in a controlled ratio (1:1). Temperature may vary between 450°-700°C with the optimum around 635°C. Gases from reactors are quenched and the excess methanol in the resulting methanol-formaldehyde solution is removed by fractionation.

In the direct oxidation of methanol to formaldehyde in the presence of iron-molybdenum oxide catalyst, a low (5-10%) methanol concentration stream in air is used. The product is essentially free of methanol.

Formaldehyde may also be produced in a vapor-phase oxidation of propane-rich LPG. However, this process has not been used since February 1973 when Celanese Corporation closed its Bay City, Texas plant.

2. Input Materials - (data for silver-catalyzed, oxidation-dehydrogenation process)

Methanol - 438 g/kg of 37% formaldehyde

Air - 888 g/kg of 37% formaldehyde

3. Operating Parameters

1) Oxidation - dehydrogenation

|                |                            |
|----------------|----------------------------|
| Temperature:   | 635°C (600-700°C) (1175°F) |
| Pressure:      | 146 kPa (1.44 atm)         |
| Catalyst:      | crystalline silver         |
| Reaction time: | 0.5 second                 |

2) Direct oxidation

|              |                        |
|--------------|------------------------|
| Temperature: | 300-400°C (572-752°F)  |
| Pressure:    | ~100 kPa (atmospheric) |
| Catalyst:    | iron-molybdenum oxide  |

4. Utilities - Basis: 45.4Gg/yr (100 M lb/yr) capacity for production of 37% HCHO by silver-catalyzed dehydrogenation-oxidation

Water, cooling - 88.3 dm<sup>3</sup>/sec (1400 gpm)

Water, process - 2.4 dm<sup>3</sup>/sec (38 gpm) (includes water for steam generation)

Steam - 0.794 kg/sec (6300 lb/hr)

Power - 107 kW (143 hp)

5. Waste Streams - Off-gases from the absorber of the absorption and purification section will lead to the following atmospheric emissions:

CO - 63.5 g/kg 37% formaldehyde

H<sub>2</sub> - 7.6 g/kg 37% formaldehyde

CH<sub>4</sub> - 1.25 g/kg 37% formaldehyde

HCHO - trace

CH<sub>3</sub>OH - trace

formic acid - in water

The major wastewater sources are the scrubber waters and the dimethyl ether by-product. The total aqueous stream should not exceed 0.42 dm<sup>3</sup>/kg (100 gal/ton) containing 1-5000 mg/dm<sup>3</sup> COD unless on-site truck washing is practiced.

6. EPA Source Classification Code - None

7. References

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973, p. 135,136.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November 1975, p. 149,150.

Hedley, W. H., et al., Potential Pollutants From Petrochemical Processes, Technomic Publishing Co., Eastport, Conn., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 86-88.

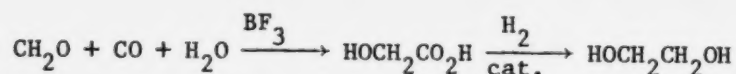
7. References (continued)

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 6," "Chemical Engineering," May 27, 1974, p. 101.

Chemistry in The Economy - American Chemical Society Publication,  
1973, p. 32.

Walker, J. F., Formaldehyde, 3rd Edition, ACS Monograph 159, 1964,  
p. 16-24.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 422.

Ethylene Glycol (from formaldehyde & CO via glycolic acid)

1. Function - Although more than 90% of ethylene glycol produced is made by catalytic oxidation of ethylene to ethylene oxide, followed by hydration, a reaction of formaldehyde, water, and carbon monoxide is also being used. These three chemicals combine at 200°C and about 70 MPa to form glycolic acid.

This is followed by hydrogen reduction of the product glycolic acid in the presence of a copper oxide-magnesium oxide catalyst (at 200°C and 10 MPa).

2. Input Materials                      Per kg ethylene glycol

|                 |       |
|-----------------|-------|
| Formaldehyde    | 650 g |
| Carbon monoxide | 625 g |
| Hydrogen        | 75 g  |
| Sulfuric Acid   | 45 g  |
| Water           | --    |

3. Operating Parameters

Temperature: 200°C (392°F)

Pressure: 70 MPa; 10 MPa for hydrogenation

Catalyst:  $\text{BF}_3$  for acid formation  $\text{CuO} - \text{MgO}$  (for hydrogenation)

Space Velocity:  $2 \times 10^4 \text{ hrs}^{-1}$

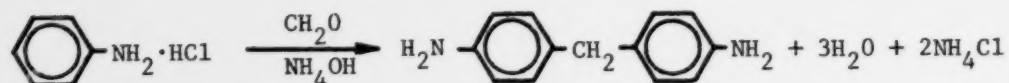
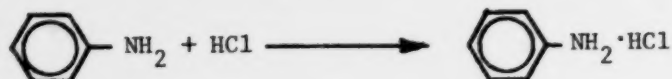
4. Utilities

Not given

5. Waste Streams - Carbon monoxide fed to the primary reaction vessel is a possible, atmospheric emission. Process slops may carry formaldehyde, methanol, higher alcohols, and organic acids to waste water flow.
6. EPA Source Classification Code - None
7. References

Faith, W. L. et al., Industrial Chemicals, 3rd Ed., John Wiley & Sons, New York, N.Y., 1965 , p. 375, 376, 377.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 294.

Methylenedianiline (condensation of aniline and formaldehyde)

1. Function - The production of methylenedianiline is a two-stage process. Aniline is neutralized with concentrated hydrochloric acid in aqueous solution at 100°C to form aniline hydrochloride. The solution is cooled to 15°C and 40% formaldehyde solution added, followed by heating at 55 - 60°C for four hours. The reaction mixture is then chilled again, and the product precipitated out with dilute ammonium hydroxide. The product may be further purified by recrystallization from alcohol or water.

2. Input Materials

Basis - 1 kg (1b) product

Aniline - 1.66 kg (3.66 lbs)

Formaldehyde (40%) - 0.68 kg (1.50 lbs)

Concentrated hydrochloric acid - 1.68 l

Ammonium hydroxide

Water - 3.57 l

3. Operating Parameters

Temperature: 55 - 60°C (131 - 140°F)

Pressure: not given

Catalyst: not given

4. Utilities - Not given

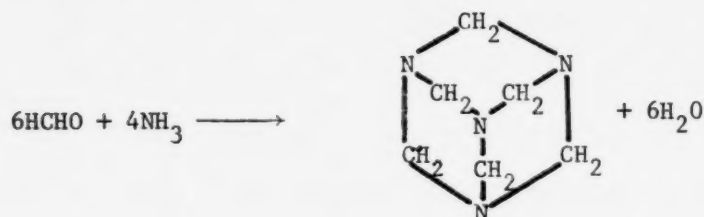


5. Waste streams - Waste water streams may contain ammonium hydroxide, ammonium chloride, and aniline compounds in solution. There will be no gaseous emissions. Resinous materials formed on contact of aniline and formaldehyde will be disposed of in process wastes.
6. EPA Source Classification Code - None
7. References

Scalon, J.T., J. Amer. Chem. Soc., 57, May, 1935, p. 890, 891.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 414.

Hexamethylenetetramine  
(condensation of formaldehyde with ammonia)



1. Function - Hexamethylenetetramine is a heterocyclic fused ring structure made by the condensation reaction of aqueous formaldehyde with liquid or gaseous ammonia.

A slight excess of ammonia may be introduced to prevent side reactions which occur at pH values below 8. The process is performed at 62-66°C and about 280 kPa (2.76 atm) in an aqueous solution within a steel, tower-type reactor.

After addition of activated charcoal for the removal of impurities, the liquid is filtered and then evaporated at reduced pressure (2-4 kPa, 0.02-0.04 atm) to collect the crystalline product. The crystalline solid mass is then centrifuged, washed, and dried to yield hexamethylenetetramine, usually of a purity better than 99%. According to industry sources, the yield is 97% from formaldehyde or 93.5% from ammonia.

2. Input Materials

Formaldehyde - 3.58 kg of 37% solution per kg of product (based on 97% yield)

Ammonia - 0.519 kg/kg product (93.5% yield)

3. Operating Parameters

Temperature: 62-66°C (144-151°F)

Pressure: 280 kPa (2.76 atm)

4. Utilities - Not given
5. Waste Streams - Reactor off-gases contain formaldehyde, ammonia, and methanol (from formaldehyde production). If this stream is incinerated,  $\text{NO}_x$  will be emitted to the atmosphere. The bleed line from the centrifuge wash, a waste water stream, will contain dissolved formaldehyde, ammonia, methanol, and hexamethylenetetramine. The drier used in final preparation of hexamethylenetetramine will emit formaldehyde, methanol, and ammonia vapors to the air.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Company, Westport, Conn., 1975.

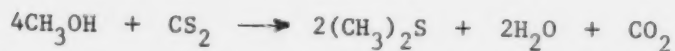
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 98.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 6," "Chemical Engineering," May 27, 1974, p. 104.

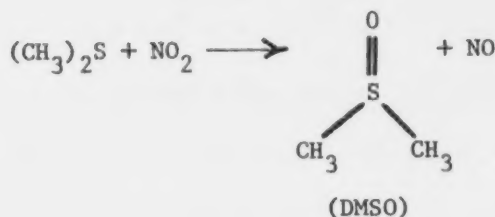
U.S. Patent 3,288,790 (November 29, 1966).

Sittig M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 364.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 563.

Dimethyl Sulfide (from methanol/carbon disulfide)

1. Function - Dimethyl sulfide may be produced by the reaction of methanol with carbon disulfide in the vapor phase in a fixed bed catalyst of activated alumina. Methyl mercaptan is the chief by-product.
2. Input Materials  
Methanol  
Carbon disulfide  
Catalyst (activated alumina)
3. Operating Parameters  
Temperature: 370-535°C (698-995°F)  
Pressure: 414 kPa (4.08 atm)
4. Utilities - Not given
5. Waste Streams - Unreacted methanol and carbon disulfide should be present along with some methyl mercaptan and possible H<sub>2</sub>S.
6. EPA Source Classification Code - None
7. References  
Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N. J., 1969, p. 266.  
U. S. Patent 2,930,816 (March 29, 1960).

Dimethyl Sulfoxide (NO<sub>2</sub> oxidation of (CH<sub>3</sub>)<sub>2</sub>S)

1. Function - Dimethyl sulfide is oxidized with a dimethyl sulfoxide solution of nitrogen dioxide in a reactor at 40-50°C. The reactor contents pass into a 100°C zone where dimethyl sulfide is sparged from the crude product with nitrogen. The crude dimethyl sulfoxide (DMSO) is then neutralized and distilled.

The flow of nitrogen dioxide into the reactor is kept insufficient to oxidize all of the dimethyl sulfide so that all the NO<sub>2</sub> is converted to NO, which is insoluble in DMSO and escapes the exit-gas stream. This stream passes through a heat exchanger to condense some of the dimethyl sulfide for recycle back to the reactor. The gases remaining are conducted to a second reactor where excess NO<sub>2</sub> converts the residual sulfide to the sulfoxide. The gases from this reactor contain substantially no organic matter and are oxidized with oxygen in a third reactor to regenerate the NO<sub>2</sub>. The gases finally pass through a DMSO scrubber to remove nitrogen dioxide prior to venting to the atmosphere.

2. Input Materials

Dimethyl sulfide

Nitrogen dioxide in dimethyl sulfoxide solution

3. Operating Parameters

Temperature: 20-50°C (68-122°F)

Pressure: 101 kPa (1 atm)

4. Utilities - not given

5. Waste Streams - The gas stream which is vented from the DMSO scrubber to the atmosphere will consist of CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>, and -0.3% nitrogen oxides (NO<sub>x</sub>). The liquid stream from the scrubber contains NO<sub>2</sub>, but this is recycled back into the process. There could also be emissions of NO, NO<sub>2</sub>, N<sub>2</sub>O<sub>3</sub>, and N<sub>2</sub> from the second and third reactors, where additional conversion was accomplished. Some liquid waste could originate from the neutralization of crude dimethyl sulfoxide.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 332, 333.

U.S. Patent 2,935,533 (May 3, 1960).

Sittig, M., Organic Chemical Process Encyclopedia - 1969, 2nd Edition, Noyes Development Corp., Park Ridge, N.J., 1969, p. 268.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 585.

SECTION VI  
NAPHTHALENE



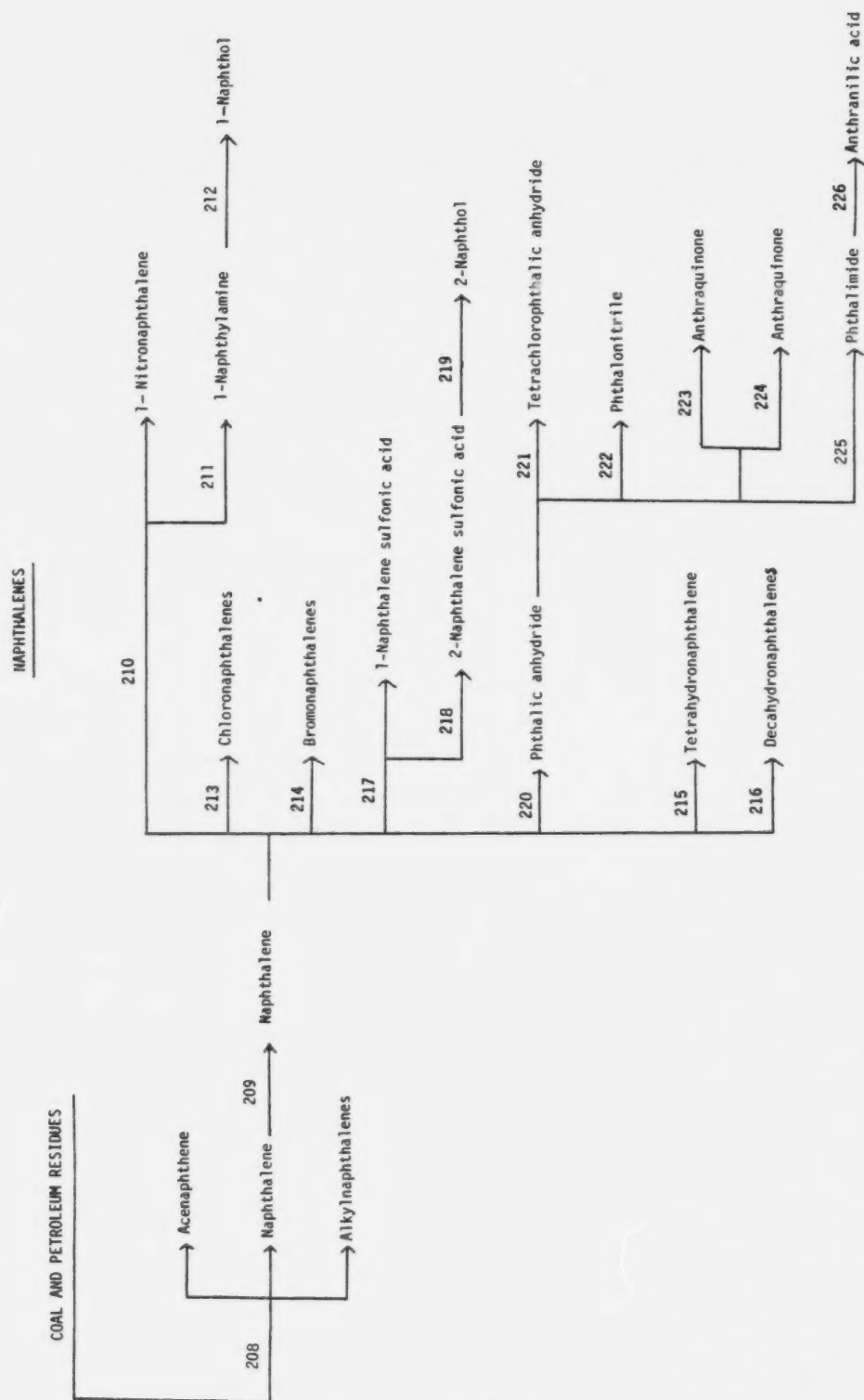


Figure 11. Naphthalene Section Chemical Tree

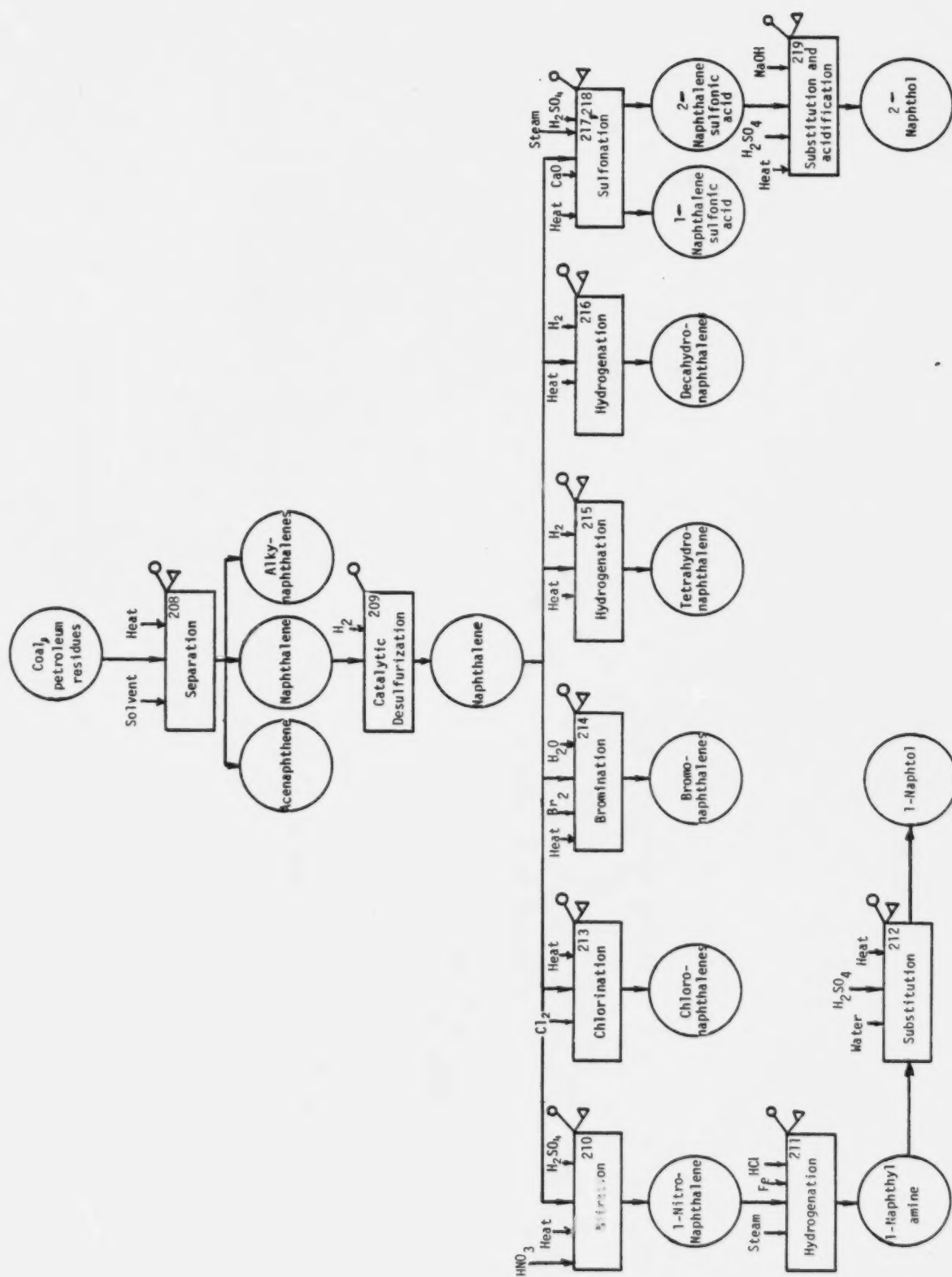


Figure 12. Naphthalene Section Process Flow Sheet

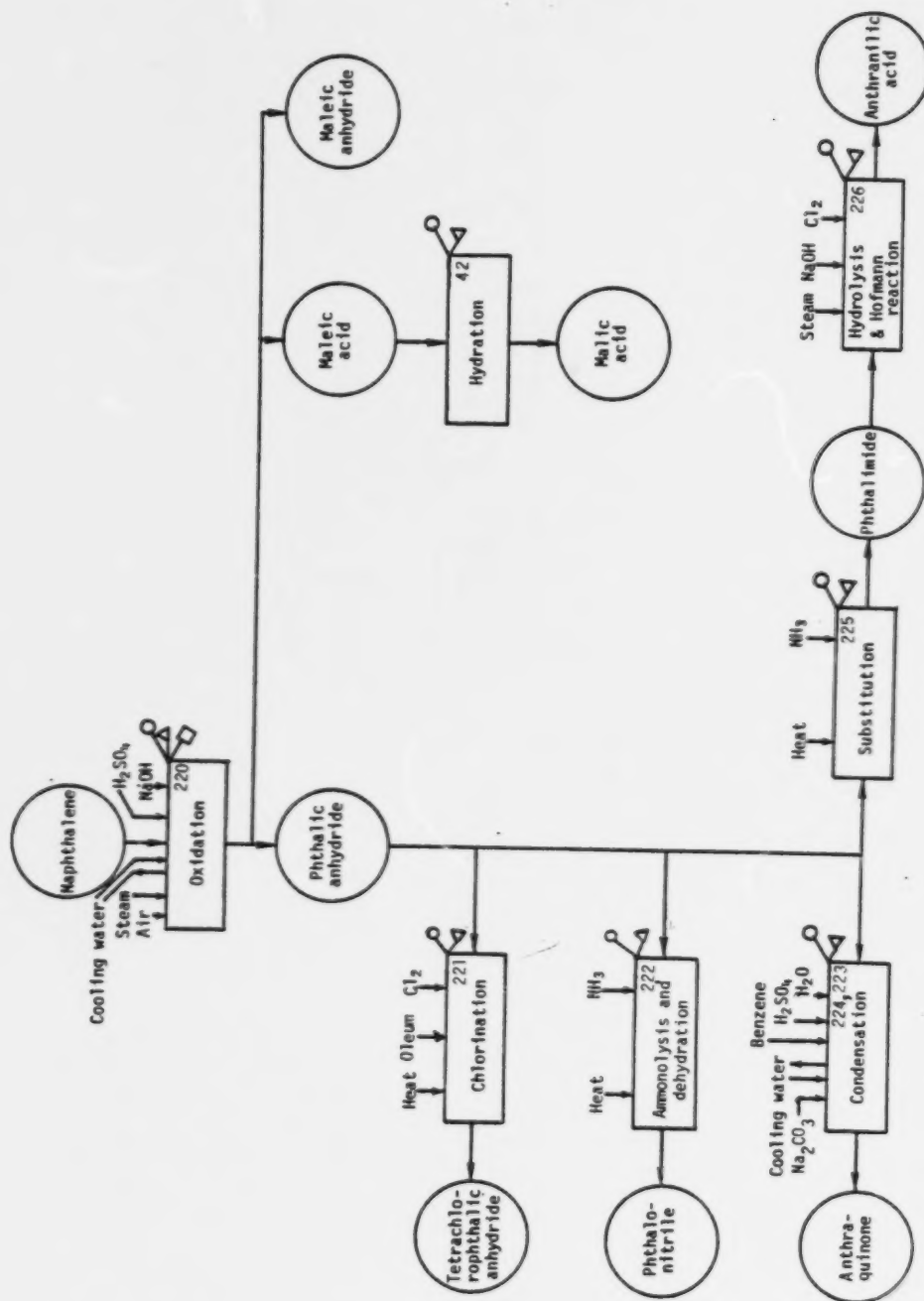


Figure 12. Naphthalene Section Process Flow Sheet (Cont.)

Separation of the Naphthalenes (Alkylnaphthalenes)

1. Function - Alkylnaphthalenes are found in coal tar, lignite tar, crude oil, drip-oil, heavy petroleum reformat, and gas oil (4%). The alkylnaphthalenes are separated from the naphthalene fractions usually either by fractionation or solvent extraction, or both, depending on the purity desired.

In the separation by fractionation, the coal tar or petroleum fraction feed is sent to a fractionator which produces a naphthalene concentrate, and a middle product of alkylnaphthalenes, and heavy aromatics bottoms. The more common present commercial sources of alkylnaphthalenes are aromatic petroleum fractions of appropriate boiling range 227 - 268°C (440 - 515°F) cut.

The solvent extraction process consists of first distilling the feed to get a middle cut in the 204 - 285°C (400 - 550°F) from the light cycle oil cut. A solvent extraction process known as the Unisorb process is then used to separate the naphthalene homologs (alkylnaphthalenes) from the lower aromatics. An extract is produced containing over 85% of the naphthalene homologs (including acenaphthene) from the charge stock while rejecting lower aromatics.

The process contains a fixed absorbent bed which is operated isothermally and at constant pressure.

2. Input Materials

coal tar  
light cycle oils  
catalytic gas oils  
drip-oil  
reformer bottoms

3. Operating Parameters - not given

4. Utilities - not given

5. Waste Streams - The air vent streams may contain paraffins or olefins as well as low boiling aromatics and solvent vapors. The solvents commonly used in solvent extraction of alkylnaphthalenes are furfural and sulfur dioxide.

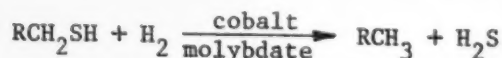
6. EPA Source Classification Code - None

7. References

Brownstein, A. M., "U.S. Petrochemicals, Technologies, Markets, and Economics," The Petroleum Publishing Company, Tulsa, Oklahoma, 1972, pp. 213-215.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), pp. 678-690.

Broughton, D. B. and Hardison, L. C., "Unisorb Extracts Naphthalene Homologs," Hydrocarbon Proc. and Petrol. Refiner, 1962, 41(5), 125-128.

Desulfurization of Hydrocarbons

1. Function - Hydrocarbon feeds from petroleum sources may contain significant amounts of sulfur containing compounds principally hydrogen sulfide and mercaptans. If these stocks are to be used in reactions involving catalysts, which are "poisoned" by sulfur compounds, these compounds must then be removed.

There are three methods of treating hydrocarbon feeds to eliminate the undesirable sulfur compounds. These may be classified as 1) oxidation, 2) catalytic desulfurization and 3) extraction.

Oxidation - Mercaptans are converted to disulfides by exposing the hydrocarbon stream to cupric chloride,  $\text{CuCl}_2$ . The copper salt may be deposited on an inert substrate and used as a slurry or as a fixed catalytic bed. Sulfur compounds are converted to the inactive disulfides, but are still present in the feed.  $\text{CuCl}_2$  may be regenerated with air either during or after the reaction.

Catalytic desulfurization - Mercaptans are converted to the lower boiling hydrocarbons by loss of hydrogen sulfide. Hydrogen and a cobalt molybdate or alumina catalyst are used. Oxygen and nitrogen compounds behave similarly to sulfur compounds and thus this catalytic desulfurization process has become important in the upgrading of reformer feed stocks. Commercial processes use temperatures of 350-450°C with pressures up to 1500 psig (100 Kg/cm<sup>2</sup>).

Extraction - In some cases, the sulfur containing organics are extracted and recovered from the hydrocarbon stock by adding an organic solvent to the caustic soda (or potash) which is being used as the extraction liquid. The solution is subsequently regenerated by air blowing to oxidize mercaptans to disulfides.

2. Input Materials

Naphthalene feed

Hydrogen

Catalyst - cobalt molybdate

3. Operating Parameters

Temperature 350-450°C (662-842°F)

Pressure up to 10.34 MPa (102 atm)

Catalyst cobalt molybdate

4. Utilities

Not given

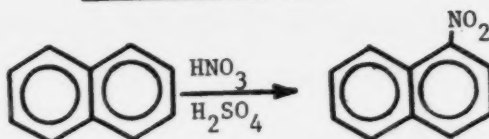
5. Waste Streams - Hydrogen sulfide, ammonia, mercaptans

6. EPA Source Classification Code - None

7. References

Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4  
(1972), p. 55-56.



1-Nitronaphthalene

1. Function - 1-Nitronaphthalene is prepared by nitrating naphthalene with mixed acid at 50-60°C. The organic phase is separated and washed with hot water until free of acids. The product contains about 0.5-1% 2,4-dinitronaphthalene and 3% 2-nitronaphthalene. These are easily removed by crystallization or by sweating (partial melting). The nitration of naphthalene gives a 94% yield of the 1-isomer. The relatively small amount of 2-isomer is easily removed with the other by-products by crystallization from alcohol.
2. Input Materials  
Naphthalene  
Mixed Acids (1 part 62%  $\text{HNO}_3$  + 3 parts 80%  $\text{H}_2\text{SO}_4$ ).
3. Operating Parameters  
Temperature: 50-60°C (122-140°F)  
Pressure: 100 KPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Air vent streams may contain oxides of nitrogen. Waste streams from the washing and purification processes contain nitric and sulfuric acids, naphthalene,  $\alpha$ -nitronaphthalene,  $\beta$ -nitronaphthalene, 2,4-dinitronaphthalene, and alcohols.
6. EPA Source Classification Code - None

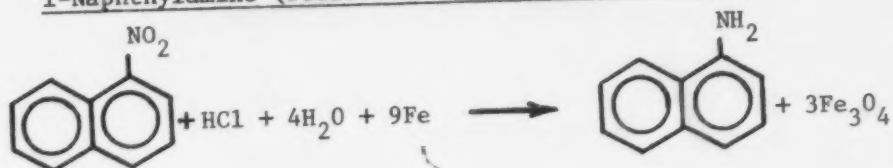
7. References

Kirk and Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 83.

Ibid., Vol. 13 (1967) p. 704.

Howe, A. P. and Hass, H.B., Ind. Eng. Chem., 38, 251, (1946).

Astle, M. J., Industrial Organic Nitrogen Compounds, Reinhold Publishing  
Corp., New York, N.Y., 1961 , p. 320-21.

1-Naphthylamine (reduction of 1-nitronaphthalene)

1. Function - 1-Naphthylamine is prepared by the catalytic reduction of 1-nitronaphthalene with iron powder and hydrochloric acid. The product mixture is made alkaline and 1-naphthylamine is distilled out with superheated steam. The yield in this process approximates 96%. By-products of this reaction are 2-naphthylamine, 1,5-naphthalene diamine and 1,1'-binaphthylamine.

2. Input Materials

1-Nitronaphthalene

Iron powder

Hydrochloric acid (dilute)

3. Operating Parameters

Temperature: 80°C

Pressure: 100 kPa (1 atm)

4. Utilities - Not available

5. Waste Streams - Air vent streams would include HCl vapor and hydrogen.

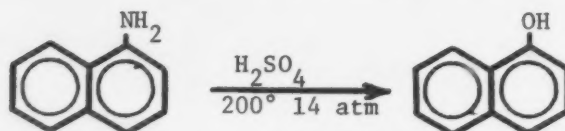
Waste water streams contain hydrochloric acid, iron salts (including chlorides), some 1-naphthylamine and 1-nitronaphthalene.

6. EPA Source Classification Code - None

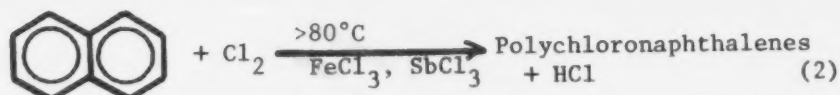
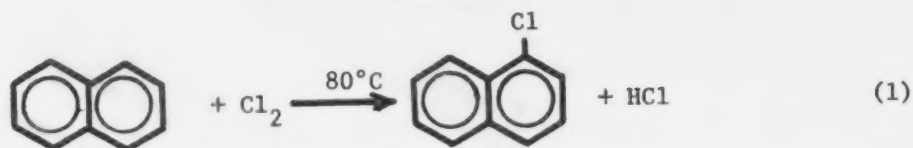
7. References

Kirk and Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 83.

Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4 (1972), p. 520.

1-Naphthol (from 1-naphthylamine)

1. Function - The best and most economical process for the production of 1-naphthol is the hydrolysis of 1-naphthylamine in aqueous sulfuric acid at 200°C and 14 atm. pressure. The yield is 95% and the product is pure. The purity of the product gives this process a distinct advantage over the alkali fusion of the sulfonic acid derivative, the method of choice for 2-naphthol, since the product purity from this process is often too low for many applications.
2. Input Materials  
1-Naphthylamine 1.06 kg/kg product  
Sulfuric acid (aqueous)
3. Operating Parameters  
Temperature - 200°C (392°F)  
Pressure - 1.42 MPa (14 atm)
4. Utilities - not given
5. Waste Streams - Effluents would contain ammonium sulfate, sulfuric acid, 1-naphthylamine and 1-naphthol.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition.  
Interscience Publishers, New York, N.Y., Vol. 13 (1967) p. 717.  
Chemical Technology, Barnes and Noble, New York, N.Y., Vol. 4 (1972) p. 326.

CHLORONAPHTHALENES

1. Function - Commercial quantities of 1-chloronaphthalene and mixtures of polychloronaphthalenes are produced by passing chlorine gas into molten naphthalene (80°C). If 1-chloronaphthalene production is favored, catalysts are not normally required.

If a polychloronaphthalene mixture is the desired product, ferric or antimony chloride catalyst must be added to the reaction mixture to promote chlorine addition. Chlorination is begun at 80°C, and the temperature is slowly raised as the reaction proceeds. During the process, the chlorination mixture is continually agitated.

When the desired point has been reached, the chlorination mixture is neutralized by stirring in the molten state with aqueous alkali, washed with water, and dried under vacuum.

2. Input Materials

Naphthalene

Chlorine

Sodium hydroxide

Water

3. Operating Parameters

Temperature -  $\geq 80^{\circ}\text{C}$  ( $176^{\circ}\text{F}$ )

Pressure - not given

Catalyst - for polychloronaphthalenes  $\text{FeCl}_3$  or  $\text{SbCl}_3$  (0.5%)

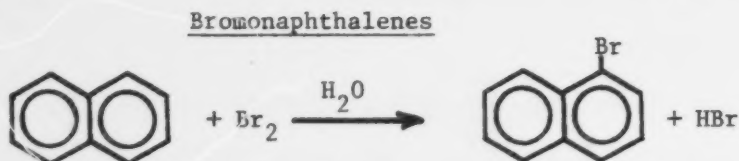
4. Utilities - Not given

5. Waste Streams - Wastewater streams from washing operations probably contain sodium chloride, sodium hydroxide, and traces of naphthalene and chlorinated naphthalenes. Chlorine gas may be discharged from various processing equipment.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1964) p. 300.



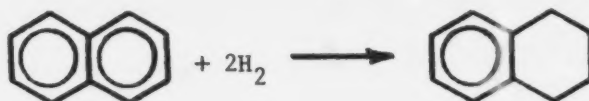
1. Function -  $\alpha$ -Bromonaphthalene and lesser amounts of dibromonaphthalenes are produced by the interaction of naphthalene and bromine in carbon tetrachloride or water. Iron catalysts are required if carbon tetrachloride serves as the reaction medium. Hydrogen bromide by-product is allowed to escape, preferably being washed by incoming raw material. The crude product is then dried and fractionated, giving  $\alpha$ -bromonaphthalene in 72 - 75% yield.
2. Input Materials  
Naphthalene - 0.82 - 0.86 kg/kg product  
Bromine  
Water or carbon tetrachloride
3. Operating Parameters  
Temperature: 100°C (212°F)  
Pressure: not given  
Catalyst: iron (in CCl<sub>4</sub>)
4. Utilities - Not given
5. Waste Streams - Air vent streams contain hydrogen bromide, the principal by-product of the reaction. Carbon tetrachloride will be present in the air vent streams from solvent recovery systems, when this solvent is used as the reaction medium. Waste streams will contain HBr, naphthalene, and some bromonaphthalenes when water is used as the solvent medium. Sodium bromide will be present in waste water when caustic soda is used to neutralize the HBr absorbed in the water.



6. EPA Source Classification Code - None

7. Reference

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 775.

Tetrahydronaphthalene

1. Function - 1,2,3,4-Tetrahydronaphthalene, more commonly known as tetralin, is produced exclusively by the catalytic hydrogenation of naphthalene. This reduction is carried out at  $150^{\circ}\text{C}^*$  in the presence of nickel or modified nickel catalysts.

Since active nickel catalysts are poisoned by sulfur compounds, represented predominately in naphthalene by thianaphthene, commercial naphthalene must be desulfurized prior to hydrogenation. This is accomplished by treatment with sodium or by a catalytic dehydrosulfurizing process.

2. Input Materials

Naphthalene (desulfurized)

Hydrogen

3. Operating Parameters

Temperature:  $150^{\circ}\text{C}$  ( $302^{\circ}\text{F}$ )

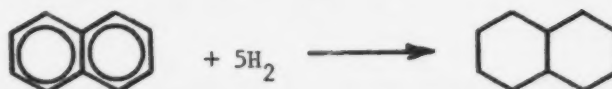
Pressure: 100 - 200 KPa (1 - 2 atm)

Catalyst: nickel or modified nickel

4. Utilities - Not given

- \* Heat-exchanges are necessary to control the temperature of this exothermic reaction, since destructive hydrogenation occurs at high temperatures.

5. Waste Streams - Air vent streams from the reactor contain hydrogen and may have small quantities of tetrahydronaphthalene and naphthalene. When the product is purified by extractive distillation the air vent streams may contain tetrahydronaphthalene, naphthalene and some solvent (diethylene glycol for example).
6. EPA Source Classification Code - None
7. References
- Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 676-77.

Decahydronaphthalenes

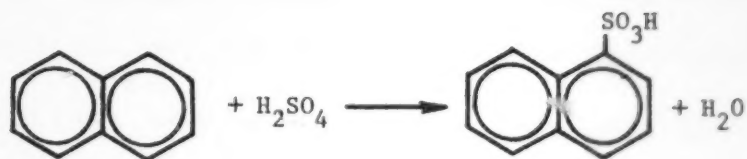
1. Function - Commercial decahydronaphthalene, a mixture of cis- and trans-isomers more commonly known as Decalin, is prepared by the catalytic hydrogenation of naphthalene.\* The reaction may be carried out in the fused-state (above 100°C) or in the liquid phase at 2.5 - 4.0 MPa (25 - 40 atm) and 200 - 260°C. Both process variations employ copper or nickel catalysts.
2. Input Materials  
Naphthalene (desulfurized)  
Hydrogen
3. Operating Parameters  
Temperature: fused state - >100°C (212°F)  
liquid phase - 200 - 260°C (232-500°F)  
Pressure: fused state - not given  
liquid phase - 2.5 - 4.0 MPa (25-40 atm)  
Catalyst: copper or nickel
4. Utilities - Not given
5. Waste Streams - Air vent streams from the reactor will contain hydrogen and some naphthalene and decahydronaphthalene. Air vent streams from the purification system contain naphthalene decahydronaphthalene and solvent when extractive distillation is used to purify the product.

\* The naphthalene feed is desulfurized by the methods discussed in Process No. 209.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 677.

1-Naphthalenesulfonic Acid

1. Function - Commercially, 1-naphthalenesulfonic acid is prepared by sulfonating naphthalene with 98% sulfuric acid below 60°C. Isolation is accomplished by liming, conversion of the calcium salt to the sodium salt by soda ash, and drying. The technical product contains about 77.5% 1-naphthalenesulfonate, 10.2% 2-naphthalenesulfonate, 5.7% disulfonate, 2.7% sodium sulfate, and 3.7% water.
2. Input Materials  
Naphthalene  
Sulfuric acid (98%)  
Lime  
Soda ash
3. Operating Parameters  
Temperature - <60°C (140°F)  
Pressure - 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Air vent streams from the reactor will contain some sulfur dioxide and small quantities of naphthalene. The overhead gases from the concentrator contain sulfur dioxide and naphthalene. Calcium sulfate and calcium carbonate are recovered from neutralization and washing steps. Waste wash water contains some sulfuric and naphthalene sulfonic acids.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 700.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4  
(1972), p. 597.



2-Naphthalenesulfonic acid

1. Function - 2-Naphthalenesulfonic acid is commercially prepared by treating naphthalene with about one part of 93-96% sulfuric acid at 160°C.

1-Naphthalenesulfonic acid, which constitutes about 15% of the crude product, is hydrolyzed back to naphthalene by steam, and the latter is recovered by steam distillation. The sulfonation mixture is then added to water, and 2-naphthalenesulfonic acid is precipitated as the sodium salt by the addition of sodium chloride.

2. Input Materials

Naphthalene

Sulfuric acid (93-96%)

Sodium chloride

Water

3. Operating Parameters

Temperature - 160°C (320°F)

Pressure - Not given

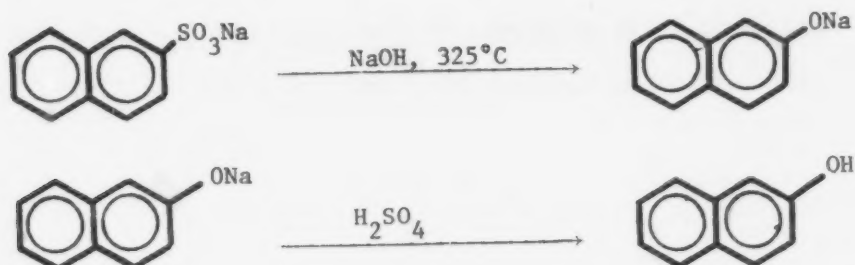
4. Utilities - Not given

5. Waste Streams - Sodium chloride, sodium sulfate, and caustic acid may be present in process wastes.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13, (1967), p. 700.

2-Naphthol (from 2-naphthalenesulfonic acid)

1. Function - In commercial practice, 2-naphthol is prepared by fusing the sodium salt of 2-naphthalenesulfonic acid with sodium hydroxide in a cast-iron or nickel-steel kettle at 325°C. The melt is run into cold water, acidified with sulfuric acid, and the free 2-naphthol is separated. The product is washed well with water, distilled in vacuo, and sublimed. The yield is almost 80% of the theoretical.
2. Input Materials

2-Naphthalenesulfonic acid (sodium salt) - 1.80 kg/kg product

Sodium hydroxide

Sulfuric acid

Water
3. Operating Parameters

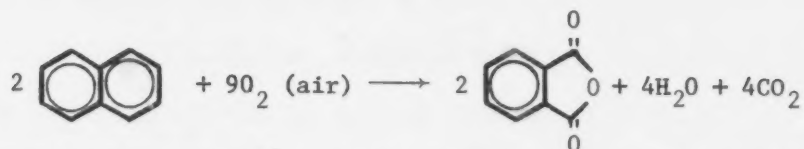
Temperature: 325°C (617°F)

Pressure: not given
4. Utilities - Not given
5. Waste Streams - The waste water from washing operations probably contains quantities of sodium sulfate, naphthalenesulfonic acids, and naphthols.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13 (1967) p. 718.

Phthalic Anhydride (from naphthalene)

1. Function - As of January 1, 1975, 36% of the U.S. capacity for phthalic anhydride production was based on naphthalene feedstock. Both petroleum naphthalene ( $>80^{\circ}\text{C}$ ) and desulfurized coal-tar naphthalene ( $78^{\circ}$ ) are converted to phthalic anhydride by vapor-phase air oxidation in the presence of a vanadium pentoxide catalyst.

There are three processes in use for the air oxidation of naphthalene. Two of these include a fixed catalyst bed process and these are adaptable to both naphthalene and o-xylene feed stocks. The third process involves a fluidized catalyst bed and has been applied only to naphthalene. A significant by-product of all three processes is maleic anhydride and maleic acid. Small amounts of benzoic acid are recovered from the fixed bed processes.

The most widely used oxidation processes are the fixed bed processes. These differ in the catalyst composition employed and the temperature range of operation. The original process employed a catalyst consisting of 65%  $\text{V}_2\text{O}_5$ , 30%  $\text{MoO}_3$  and 5%  $\text{CuO}$  or  $\text{Mn}_3\text{O}_4$ . It operated at  $400\text{--}475^{\circ}\text{C}$  and gave yields of phthalic anhydride of approximately 65%.

The von Heyden process, a low-temperature, fixed-bed air oxidation, also accounts for considerable naphthalene-based phthalic anhydride production. Reaction temperatures are maintained in the  $350\text{--}360^{\circ}\text{C}$  range with 4 - 5 sec contact time. The catalyst is usually vanadium

pentoxide on silica with 20-30% potassium sulfate. Yields in the neighborhood of 82% are obtained by this process with limited by-production of maleic anhydride, maleic acid, etc.

The third process employs an air-fluidized bed of  $V_2O_5$  into which is injected naphthalene in vapor form. The bed is maintained at 340-380°C and 1 atmosphere. The air/feed ratio can be maintained at 2 to 3x a lower value than in the fixed bed system. It is not possible to use o-xylene as a feedstock in this system and as a result the use of this system is decreasing as the difficulty in obtaining naphthalene feedstock increases. Yields from this process approximate 85%. The vaporous effluent in all these processes is passed through heat exchangers where phthalic anhydride crystallizes and deposits on the walls. Heat is then applied and the crude product is melted out and collected. Using this procedure 98-99% of the phthalic anhydride in the effluent is recovered.

The crude product is purified by a chemical soak in sulfuric acid and caustic followed by a heat soak at 150-250°C. This heat treatment removes water and other impurities such as maleic acid and anhydride as well as benzoic acid. The residual phthalic anhydride is vacuum distilled in batch or continuous operation.

2. Input Materials - Basis - 1 metric ton phthalic anhydride

Naphthalene (>80° or desulfurized) 1,250 kg (2,756 lbs)

Air (15°C, 59°F) 26,000 m<sup>3</sup> (918, 181 ft<sup>3</sup>)

Sulfuric acid

Sodium hydroxide

Water

### 3. Operating Parameters

|                |                             |                                                                                                           |
|----------------|-----------------------------|-----------------------------------------------------------------------------------------------------------|
| Temperature:   | High temperature, fixed bed | - 400-475°C (752-887°F)                                                                                   |
|                | Von Heyden                  | 350-360°C (662-680°F)                                                                                     |
|                | Fluidized bed               | 340-380°C (644-716°F)                                                                                     |
| Pressure:      | Von Heyden                  | 48-55 kPa (0.47-0.54 atm)                                                                                 |
|                | Fluidized bed               | 101 kPa (1 atm).                                                                                          |
| Catalyst:      | High Temperature, fixed bed | 65° V <sub>2</sub> O <sub>5</sub> , 30% MoO <sub>3</sub> , 5%<br>(CuO or Mn <sub>3</sub> O <sub>4</sub> ) |
|                | Von Heyden                  | V <sub>2</sub> O <sub>5</sub> on SiO <sub>2</sub> + 20-30%<br>K <sub>2</sub> SO <sub>4</sub>              |
|                | Fluidized bed               | Finely divided V <sub>2</sub> O <sub>5</sub>                                                              |
| Reaction Time: | Fluidized bed               | 19-20 sec                                                                                                 |
|                | Von Heyden                  | 4-5 sec                                                                                                   |
|                | Fixed bed                   | 0.1-0.6 sec                                                                                               |

### 4. Utilities\* - Basis 0.72 kg/sec capacity (50M lb/yr)

#### Water

Cooling, makeup (steam generation), makeup (cooling) - 61,000 gph

#### Electricity

Process - 2.0 MW

Utilities - 88 kW

Fuel - 3.3 dm<sup>3</sup>/sec average (420 cfh)

### 5. Waste Streams\*

Spray scrubber effluent (water)

Phthalic anhydride - trace

Maleic anhydride - 16.7 Kg/Mg phthalic anhydride

Spray scrubber effluent (air)

\* These values are characteristic of the first fixed-bed process.



5. Waste Streams (continued)

Naphthalene - trace

Phthalic anhydride - 9.5 Kg/Mg phthalic anhydride product

Maleic anhydride - 26 Kg/Mg phthalic anhydride

Other - 23.7 Kg/Mg phthalic anhydride (assumed to be organic in nature)

Phthalic anhydride recovery columns (solid)

Phthalic anhydride - 69.3 kg/Mg phthalic anhydride

Other - 51 kg/Mg phthalic anhydride (assumed to be organic in nature;  
specific compound information not available)

6. EPA Source Classification Source - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 8," "Chemical Engineering," July 22, 1974, p. 109.

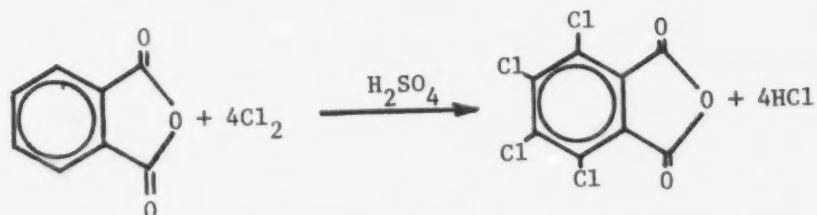
Sittig, M., Chemicals from Aromatics, Noyes Development Co.,  
Park Ridge, N.J., 1966, p. 50.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 450.

"1971 Petrochemical Handbook," "Hydrocarbon Processing," November  
1971, p. 189.

Sittig, M., Pollution Control in the Organic Chemical Industry,  
Noyes Data Corp., Park Ridge, N.J., 1974, p. 186-188.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 658-660.

Tetrachlorophthalic Anhydride

1. Function - Tetrachlorophthalic anhydride is produced by the high-temperature chlorination of phthalic anhydride in fuming sulfuric acid. Antimony pentachloride may be used as a catalyst.
2. Input Materials  
Phthalic anhydride  
Chlorine  
Sulfuric acid (fuming)
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Wastewater from the acid scrubber may contain sodium hydroxide, and traces of phthalic anhydride, and various chloro-substituted phthalic anhydrides.
6. EPA Source Classification Code -None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 446.

Phthalonitrile (from phthalic anhydride)

1. Function - One competitive route to phthalonitrile involves the vapor-phase reaction of phthalic anhydride and ammonia. This conversion takes place at high temperatures over an alumina catalyst.

Phthalimide and/or phthalamide intermediates are probably involved.

2. Input Materials

Phthalic anhydride

Ammonia

3. Operating Parameters

Temperature - Not given

Pressure - Not given

Catalyst - Alumina

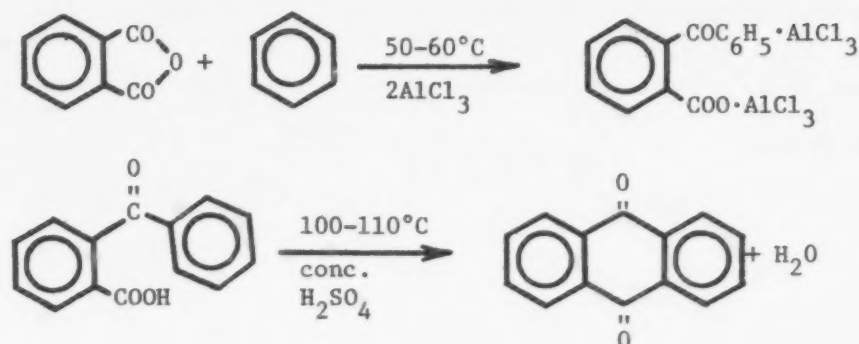
4. Utilities - Not given

5. Waste Streams - Effluents from the ammonia stripper and/or separator probably contain ammonia, phthalic anhydride, phthalonitrile, and reaction intermediates such as phthalamide and phthalimide.

6. EPA Source Classification Code - None

7. References

- Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 447.
- Throdahl, M. C., Zerbe, R. O., and Beaver, D. J., Ind. Eng. Chem.,  
43, 926 (1951).

Anthraquinone (solvent method)

1. Function - The most frequently used route to anthraquinone involves the condensation of phthalic anhydride and benzene to give *o*-benzoylbenzoic acid which undergoes ring closure by dehydration. Overall this can be considered a modified Friedel-Crafts reaction. Two general methods are utilized to produce the product, the solvent method and the ball mill method.

In the solvent method, phthalic anhydride is added to a cast-iron kettle containing aluminum trichloride and a large excess of benzene. An aluminum chloride complex of *o*-benzoylbenzoic acid is formed with an evolution of heat. The temperature is regulated so that it slowly reaches 50-60°C. Hydrogen chloride evolved during the reaction is discharged to a condenser-scrubbing system.

When the evolution of HCl is complete the reaction mass is transferred to an acid proof reactor containing dilute  $\text{H}_2\text{SO}_4$  which decomposes the complex to *o*-benzoylbenzoic acid and water soluble aluminum sulfate. The water and benzene solutions are separated and the *o*-benzoylbenzoic acid recovered by treating the benzene phase with aqueous sodium

carbonate. The benzene is separated, distilled and recycled. The sodium salt of o-benzoylbenzoic acid is neutralized and filtered out of the aqueous phase.

The o-benzoylbenzoic acid is washed, dried and treated with concentrated  $H_2SO_4$  or oleum at 100-110°C. Practically quantitative yields of high-purity anthraquinone are obtained. If further purification is required it may be done by sublimation.

2. Input Materials

Phthalic anhydride - 0.75 kg/kg product

Benzene

Aluminum chloride (anhydrous)

Sulfuric acid

Sodium carbonate

Sodium hydroxide (HCl scrubber)

Water

3. Operating Parameters

Temperature: condensation - 50-60°C (122-140°F)

dehydration - 100-110°C (212-230°F)

Pressure: not given

4. Utilities - Not given

5. Waste Streams - The principal pollutant sources in this process are most likely wastewater effluents from the HCl scrubber, phase separations, and filtering and washing operations.

Hydrogen chloride scrubber

Sodium chloride and caustic soda are probably present in this waste stream

#### Aqueous phase separation

The discarded aqueous phase of the aluminum chloride complex decomposition product is likely to contain sulfuric acid as well as various aluminum salts.

#### Benzene extraction

The extract water probably contains quantities of benzene and other organics, i.e., purification solvents.

#### Filtering/washing operations

Hydrochloric or sulfuric acid and various sodium salts are probably the principal pollutants in the waste stream.

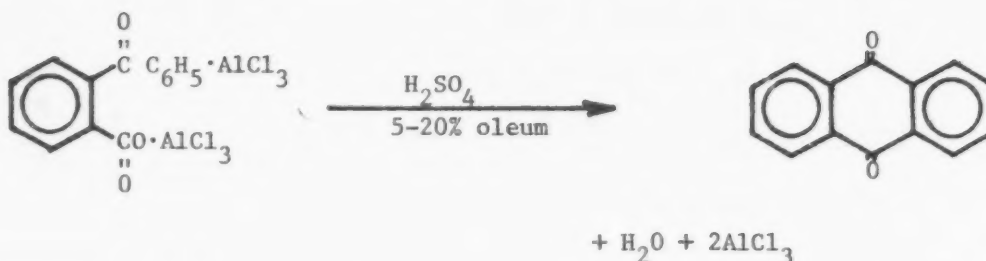
Indeterminate quantities of phthalic anhydride, benzene, and o-benzoylbenzoic acid may be present in all wastewater effluents.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 2, (1963), p. 435.



Anthraquinone (ball mill method)

1. Function - As mentioned in Process No. 223, the ball mill method is one of two general routes to anthraquinone from phthalic anhydride and benzene. In this process, the reactants are mixed in practically stoichiometrical quantities with only a slight excess of benzene present. Consequently, the product of the condensation reaction is discharged as a dry aluminum chloride complex of o-benzoylbenzoic acid which can be ring-closed directly to anthraquinone by treatment with strong sulfuric acid or 5-20% oleum.

Alternately, the complex may be anhydrously decomposed to o-benzoylbenzoic acid and subsequently dehydrated by the method described in Process No. 223. The yield and quality of the product obtained by this procedure are almost the same as in the solvent method.

However, the ball mill operation has two distinct advantages over the solvent method. Practically no solvent recovery is necessary, and the liberated hydrogen chloride is free of corrosive action since decomposition of the aluminum chloride complex is carried out anhydrously.

2. Input Materials

Phthalic anhydride - 0.75 kg/kg product

Benzene

2. Input Materials (continued)

Aluminum chloride (anhydrous)

Sulfuric acid or oleum (5-20%)

Aqueous sodium hydroxide (HCl scrubber)

3. Operating Parameters - see Process No. 224.

4. Utilities - Not given

5. Waste Streams - Wastewater from the HCl scrubber probably contains sodium chloride, sodium hydroxide, and traces of phthalic anhydride and benzene.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 436.

Phthalimide

1. Function - On an industrial scale, phthalimide is produced by saturating molten phthalic anhydride with dry ammonia and heating the mixture to 170-240°C under pressure.

Alternately, the cyclic imide can be prepared in 95-97% yield by heating the anhydride with concentrated aqueous ammonia solution and eventually raising the temperature to 300°C. Phthalimide is isolated by evaporating the product solution to dryness.

2. Input Materials

Phthalic anhydride - 1.05 kg/kg product

Ammonia (anhydrous or aqueous)

3. Operating Parameters

Temperature - anhydrous process - 170-240°C (338-464°F)

aqueous process - 300°C (572°F)

Pressure - anhydrous process - elevated

aqueous process - atmospheric

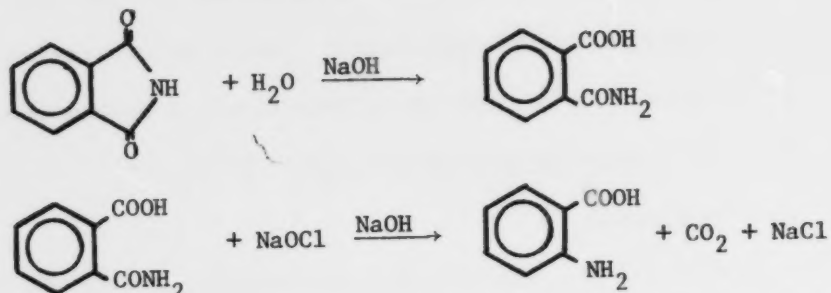
4. Utilities - Not given

5. Waste Streams - In the anhydrous process, the principal pollutant source is probably the ammonia absorber off-gas, containing ammonia and smaller quantities of phthalic anhydride. In the aqueous process, waste gases from evaporation may also contain quantities of ammonia and phthalic anhydride.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 447.

Anthranilic Acid

1. Function - Anthranilic acid is prepared in high yield by the action of sodium hypochlorite or hypobromite on phthalimide in alkaline solution at 80°C. The ring is opened by hydrolysis and the phthalamidic acid intermediate undergoes the Hofmann reaction.

Anthranilic acid is precipitated on neutralization of the alkaline solution.

In commercial operations, sodium hypochlorite or hypobromite is probably prepared in situ by passing chlorine or bromine into the sodium hydroxide solution.

2. Input Materials

Phthalimide

Sodium hydroxide

Chlorine or bromine

Water

Mineral acid

3. Operating Parameters

Temperature: 80°C (176°F)

Pressure: not given

4. Utilities - Not given

5. Waste Streams - Hypochlorous acid or the hypobromous acid may be detected in any air vent streams from the reactor. Chlorine and/or bromine will also be present. Waste water streams contain some sodium chloride and small quantities of anthranilic acid.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964). p. 434.

SECTION VII  
PARAFFINS



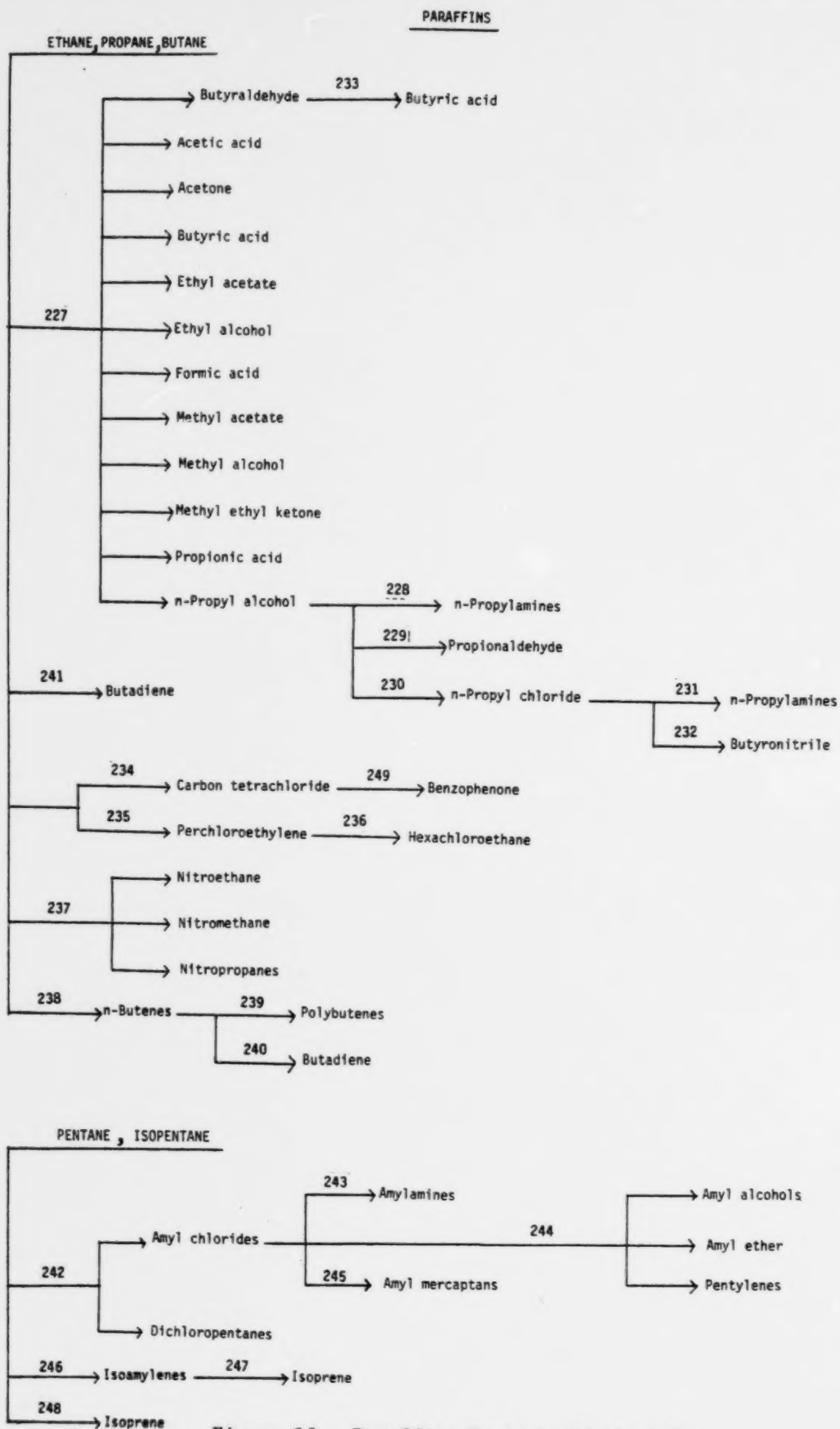


Figure 13. Paraffins Section Chemical Tree

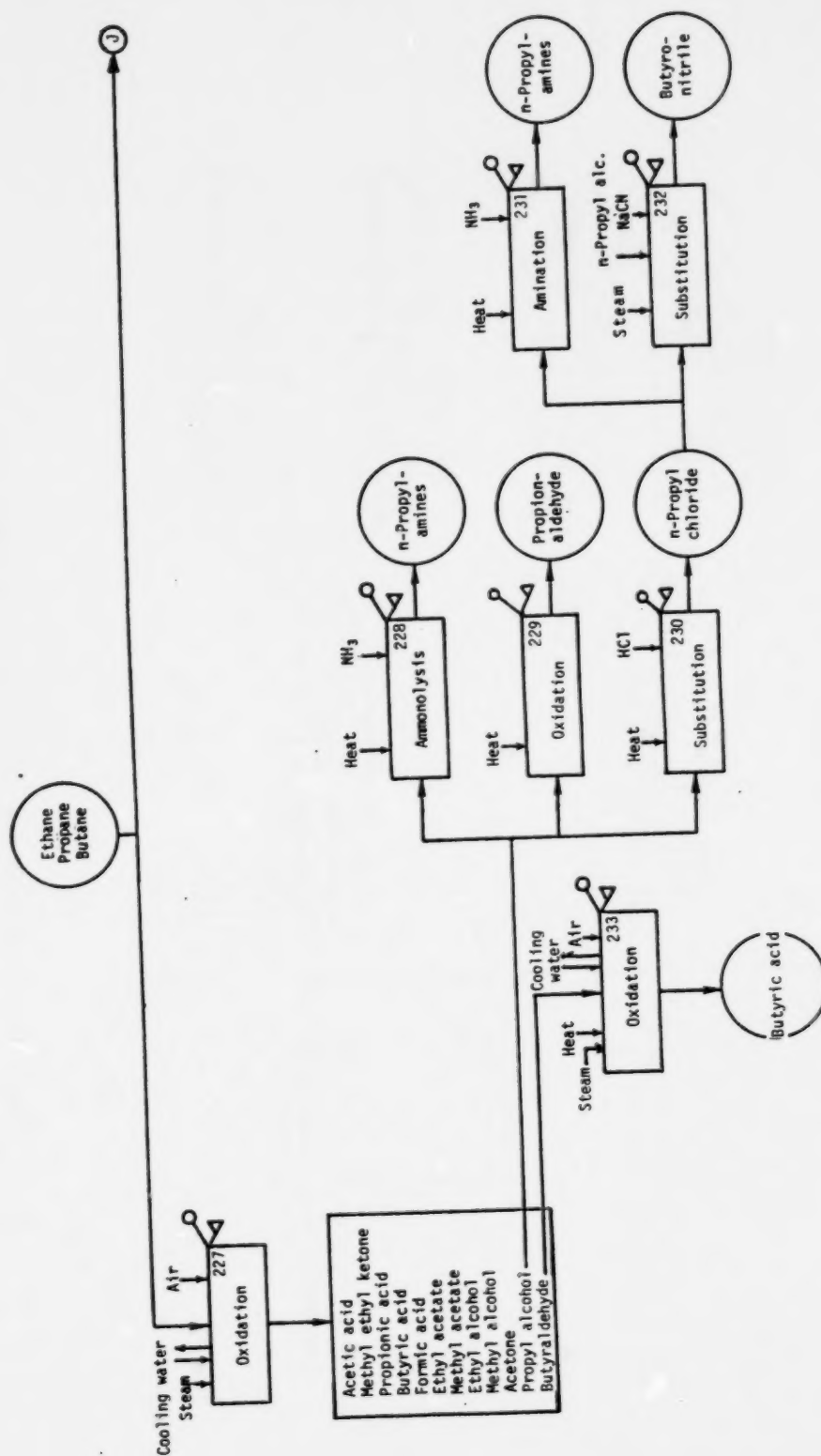


Figure 14. Paraffins Section Process Flow Sheet

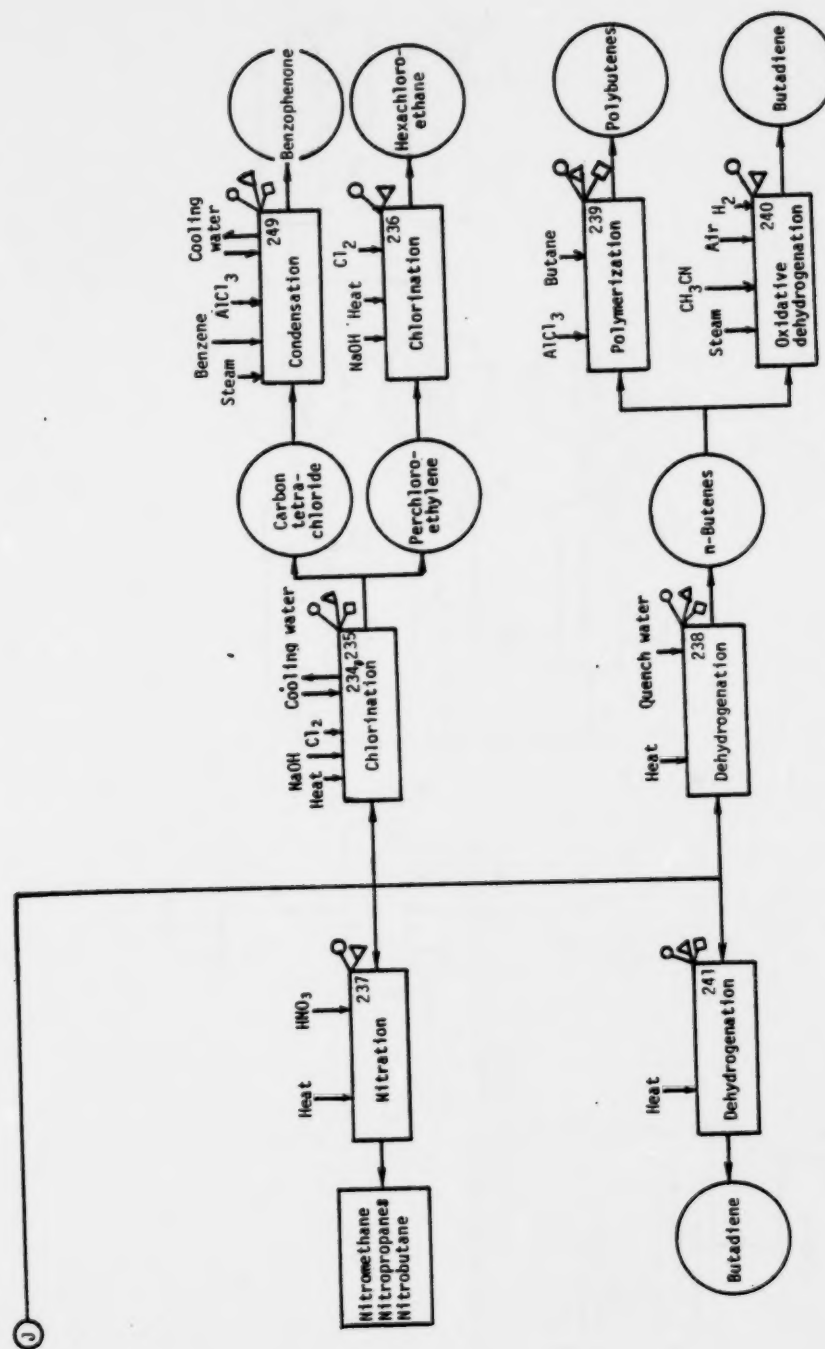


Figure 14. Paraffins Section Process Flow Sheet (Cont.)

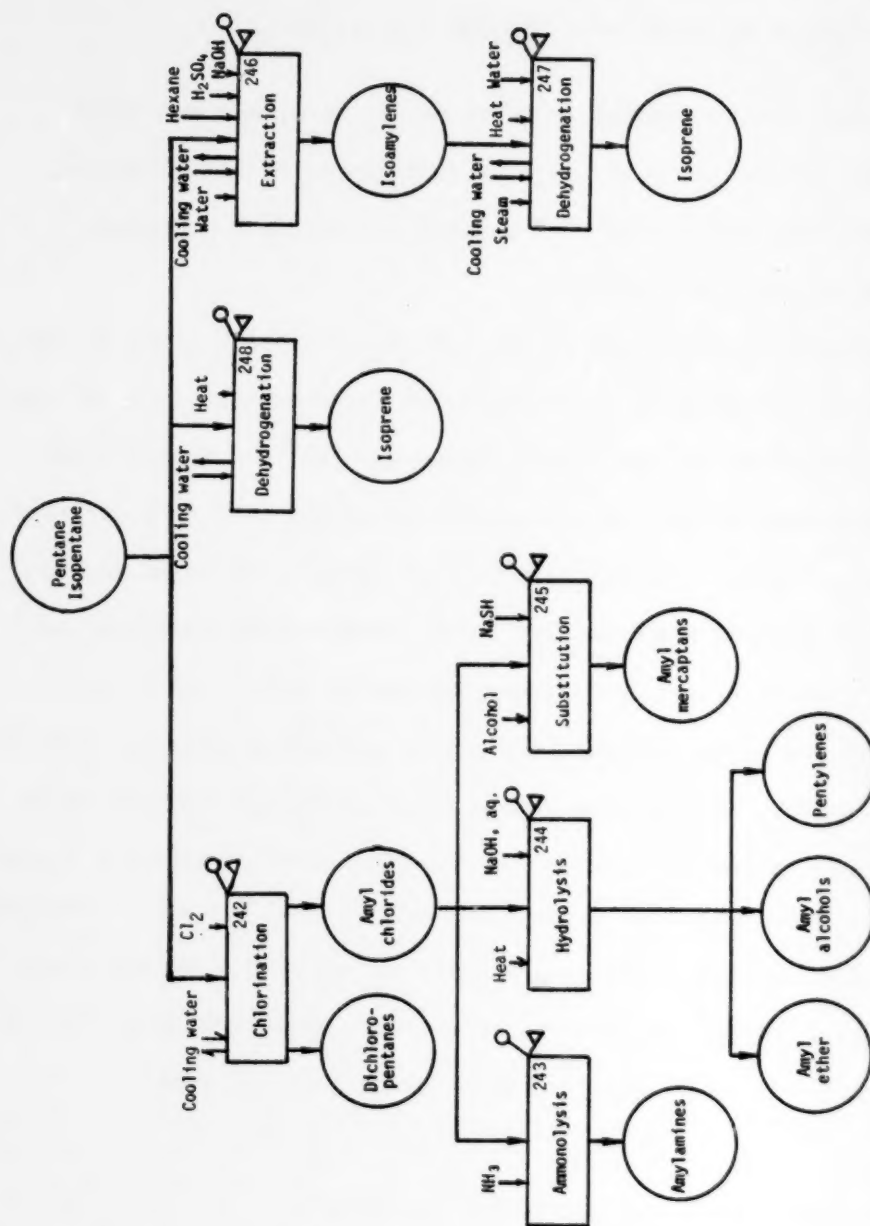
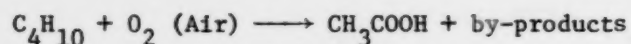


Figure 14. Paraffins Section Process Flow Sheet (Cont.)

Acetic Acid and by-products (oxidation of n-butane)

1. Function - The most economical route to acetic acid, and one which accounted for 46% of the total 1973 production in the United States, is the liquid-phase oxidation of a natural gas or light petroleum fraction containing 95% n-butane.

The oxidation of n-butane is carried out at 150-225°C and 5.5 MPa (~800 psig) in the presence of a transition-metal acetate, usually cobalt acetate. Compressed air and liquid butane are fed to a liquid phase reactor. Reaction product is withdrawn, cooled and sent to a decanter for phase separation. The hydrocarbon-rich phase is recycled to the reactor. The aqueous phase is sent to the recovery and purification system. Off-gases primarily nitrogen, oxides of carbon and n-butane, are scrubbed for butane recovery and vented through an expander turbine to recover energy. Low boiling organics are separated from the crude acetic acid by conventional distillation. Recovered by-products include methanol, acetone, n-propyl alcohol and methyl ethyl ketone. Depending on reaction conditions, formic, propionic and butyric acids and their esters (methyl, ethyl) may also be recovered. Azeotropic distillation is used to purify the crude acetic acid to glacial acetic acid.

2. Input Materials - Basis - 1 metric ton products

|           |                          |                                                                   |
|-----------|--------------------------|-------------------------------------------------------------------|
| n-Butane* | - 1.08 kg/kg acetic acid | 965 kg (2127 lbs/ton)                                             |
| Air       |                          | 3750 m <sup>3</sup> (1.32 x 10 <sup>5</sup> ft <sup>3</sup> /ton) |

---

\* The hydrocarbon feed also contains some propane, ethane, isobutane, and other lights.

3. Operating Parameters

Temperature - 150-225°C (302-437°F)

Pressure - 5.52 MPa (54.5 atm)

Catalyst - cobalt acetate

4. Utilities - Not given

5. Waste Streams - Various wastewater streams from the purification section may contain acetic acid and a variety of alcohols, aldehydes, ketones, esters, other organic acids, ethers, and high-boiling impurities. Quantities of butane, propane, ethane, etc., are probably discharged to the atmosphere from the reaction section. No specific information was available.

6. EPA Source Classification Code - None

7. References

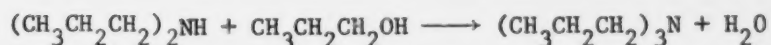
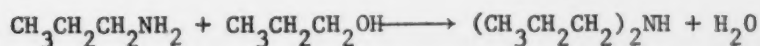
Austin, George T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 128,129.

Ibid., Part 4, April 15, 1974, p. 89,90.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 8 (1965) p. 396,397.

Lowry, R. P. and Aguilo, A., "Hydrocarbon Processing," November, 1974, p. 105.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 11,12.

n-Propyl Amines (from n-propyl alcohol)

1. Function - Propyl alcohol reacts with ammonia at moderately high temperature (300-500°C) and pressures of 1-20 MPa (10-200 atm) to yield mono-, di- and tripropyl amines. The mixture of amines formed is thought to be in equilibrium and the yield of each of them can be increased by recycling the others. The product ratio may also be controlled by the ratio of reactants and the operating temperature. A catalyst consisting of activated alumina is commonly used in these reactions. Silica, and magnesium oxide as well as alumina containing  $\text{Fe}_2\text{O}_3$ ,  $\text{TiO}_2$  and cobalt, nickel and chromium oxides have been used to promote amine formation.

2. Input Materials

n-Propyl alcohol

Ammonia

3. Operating Parameters

Temperature: 300-500°C (572-932°F)

Pressure: 1-20 MPa (10-200 atm)

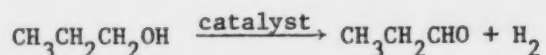
Catalyst: alumina



4. Utilities - Not given
5. Waste Streams - Waste effluents from strippers, separators, etc.,  
may contain ammonia, n-propyl alcohol, and all of the n-propylamines.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 117.

Astle, M.J., Industrial Organic Nitrogen Compounds, Reinhold Publishing  
Corporation, New York, N.Y., 1961 , p. 8-9.

Propionaldehyde (from n-propyl alcohol)

1. Function - Small quantities of propionaldehyde are produced by the dehydrogenation of n-propyl alcohol. This conversion is carried out at 200-300°C in the presence of copper compounds or iron oxide.

Reaction equipment is usually stainless steel, but aluminum is also satisfactory.

2. Input Materials - n-propyl alcohol

3. Operating Parameters

Temperature - 200-300°C (392-572°F)

Pressure - Not given

Catalyst - copper compounds (copper chromite) or iron oxide

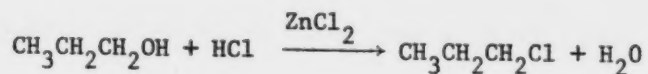
4. Utilities - Not given

5. Waste Streams - Waste gases from this process may contain hydrogen, n-propyl alcohol, and propionaldehyde.

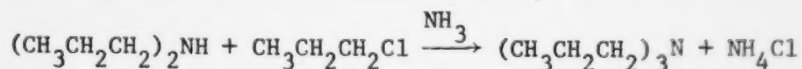
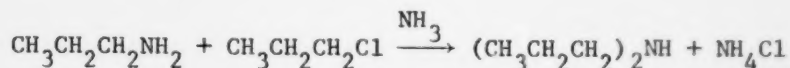
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 16 (1968), p. 550.

n-Propyl Chloride (from n-propyl alcohol)

1. Function - n-Propyl chloride is produced by heating n-propyl alcohol in concentrated hydrochloric acid. Zinc chloride catalyzes the reaction.
2. Input Materials  
n-Propyl alcohol  
Hydrochloric acid (conc.)
3. Operating Parameters  
Temperature: not given  
Pressure: not given  
Catalyst:  $\text{ZnCl}_2$
4. Utilities - Not given
5. Waste Streams - Water-spent catalyst, propyl chloride, and tars may be present in the separator waste effluents.
6. EPA Source Classification Code - None
7. Reference  
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 192, 270.

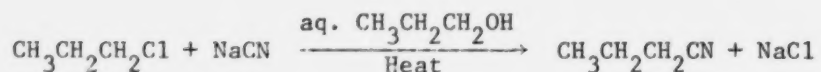
n-Propyl Amine (from n-propyl chloride)

1. Function - n-Propyl amine is commercially produced by the reaction of n-propyl chloride and ammonia. The reaction is carried out under pressure at moderately high temperatures (160-170°C). Normally the primary, secondary and tertiary amine derivatives are formed. The primary amine yield may be maximized by operating at excess ammonia concentrations. Yields of secondary and tertiary amines are increased by recycling the primary amine.
2. Input Materials  
n-Propyl chloride  
Ammonia
3. Operating Parameters  
Temperature: 160-170°C (320-338°F)  
Pressure: 2.7 MPa (27 atm)
4. Utilities - Not given
5. Waste Streams - Waste effluents from the ammonia stripper may contain quantities of ammonia, propyl chloride, and primary, secondary, and tertiary propyl amines.

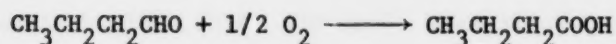
6. EPA Source Classification Code - None

7. References

Astle, M.J., Industrial Organic Nitrogen Compounds, Reinhold Publishing Corp., New York, N.Y., 1961 , p. 5.

Butyronitrile (from n-propyl chloride)

1. Function - Butyronitrile is prepared by the reaction of n-propyl chloride and sodium cyanide in aqueous n-propanol.
2. Input Materials  
n-Propyl chloride  
Sodium cyanide  
n-Propyl alcohol  
Water
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Waste streams from the purification section probably contain sodium chloride, propyl alcohol, propyl chloride, butyronitrile, and sodium cyanide. Some air emissions of propyl chloride, propanol, and hydrogen cyanide may also occur.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. supplement (1971), p. 598.

n-Butyric Acid (oxidation of n-butyraldehyde)

1. Function - Some butyric acid is prepared commercially by the oxidation of n-butyraldehyde. In this process, air or oxygen is passed into n-butyraldehyde in the presence of a catalyst such as manganese butyrate or a cobalt salt.

Yields of about 90% are possible over a wide range of temperatures.

2. Input Materials

n-Butyraldehyde - 0.91 kg/kg butyric acid

Air or oxygen

3. Operating Parameters

Temperature: 30-50°C (86-122°F)

Pressure: not given

Catalyst: 0.5% manganese butyrate

Cobalt salts

4. Utilities

Not given

5. Waste Streams - Although no information was available, some n-butyraldehyde and butyric acid are probably present in the reactor off-gas. Process slops may also be a source of these pollutants, as well as reaction by-products.

6. EPA Source Classification Code - None



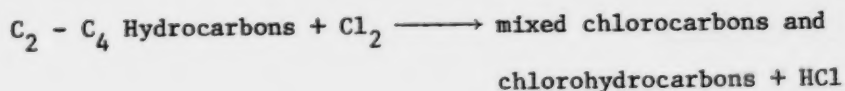
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1964). p. 880.

Chemical Technology, Barnes and Noble Books, New York, N.Y.,  
Vol. 4 (1972), p. 426.

Goldstein, R. F., The Petroleum Chemicals Industry, 2nd Edition,  
John Wiley and Sons, New York, N.Y., 1958 , p. 331.

Carbon Tetrachloride and Perchloroethylene  
(hydrocarbon chlorinolysis)



1. Function - Large quantities of perchloroethylene, carbon tetrachloride, and other chlorohydrocarbons are co-produced by the simultaneous chlorination and pyrolysis of paraffinic hydrocarbons. In commercial practice, this conversion is carried out by reacting ethane, propane, LPG, or natural gas with an excess of chlorine at 500 - 700°C.

Gaseous reaction products are quenched and most organics condensed. Any HCl remaining in the condensed crude is neutralized with dilute caustic, and the product is decanted from the aqueous phase, dried, and distilled.

Light end organics such as carbon tetrachloride and trichloroethylene\* are condensed and purified by further distillation. Perchloroethylene, hexachloroethane, and higher-boiling bottoms are separated, and the saleable compounds are neutralized, dried, and inhibited (if an olefinic linkage is present). Depending on economic factors, any of the various products may be recycled to the reactor.

\* Generally, trichloroethylene production is favored by lower reaction temperatures, i.e., 300-500°C.

2. Input Materials

Ethane, propane, LPG, or natural gas

Chlorine

Sodium hydroxide

Polymerization inhibitors

Water

3. Operating Parameters

Temperature: 500-700°C (932-1292°F)

Pressure: not given

4. Utilities

Not given

5. Waste Streams - Generally, the same types of pollution would be expected as in Process Nos. 235 and 236.

6. EPA Source Classification Code - None

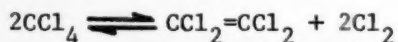
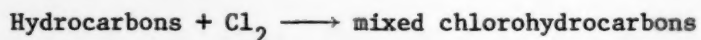
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 127.

Ibid, Part 7, June 24, 1974, p. 156.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 132, 199.

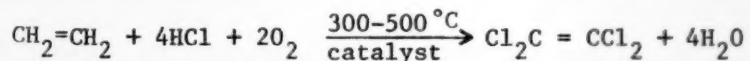
"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973, p. 114.

Perchloroethylene (chlorination of mixed hydrocarbons)

1. Function - Perchloroethylene is now produced from a mixture of hydrocarbons. The usual starting materials are methane, ethane, ethylene, LPG, propane, ethylene dichloride, or process wastes from vinyl chloride manufacture, which are chlorinated to yield saturated chlorohydrocarbons. These are then pyrolyzed to yield mixtures of predominantly trichloroethylene, carbon tetrachloride, and perchloroethylene. The desired product may be separated and the rest returned to the reactor.

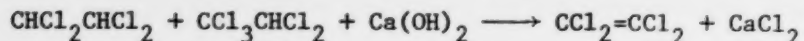
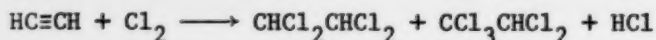
The formation of the mixed chlorohydrocarbons is carried out at 100-125°C and 5-10 atm; the pyrolysis is carried out at 400-700°C.

Perchloroethylene is also produced in a modified Deacon process which uses HCl and air:



With an excess of oxygen, the mixed product is typically 5-10% dichloroethylene, 25-35% trichloroethylene, and 50-60% perchloroethylene, which can be separated by fractionation. Fluid catalysts are commonly used; chlorination, oxychlorination and dehydrochlorination may proceed simultaneously in the same vessel.

In the past, the dominant process started with acetylene and chlorine:



This process is no longer economical.

2. Input Materials (typical)

Basis - 1 metric ton perchloroethylene and 1,350 kg HCl

Propane, kg      200 (441 lbs)

Chlorine, kg    2,500 (5,512 lbs)

3. Operating Parameters

Step one:

Temperature, °C      100-125 (212-257°F)

Pressure, MPa      0.507-1.01 (5-10 atm)

Step two:

Temperature, °C      400-700 (752-1292°F)

4. Utilities

Not given

5. Waste Streams - Although no information was available, mixed chloro-hydrocarbons and hydrogen chloride may be present in the waste gases of various production steps. Heavy ends from distillation columns are usually incinerated.

6. EPA Source Classification Code - None

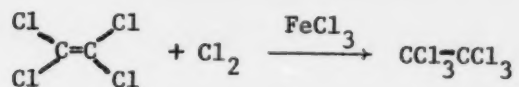
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7," "Chemical Engineering," June 24, 1974, p. 156.

Hahn, A. V., The Petrochemical Industry - Market and Economics,  
McGraw-Hill Book Co., New York, N.Y., 1970, p. 312,313.

Faith, W. L., et al., Industrial Chemicals, 3rd Edition,  
John Wiley & Sons, New York, N.Y., 1965, p. 577,578.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 606.

Hexachloroethane (from perchloroethylene)

1. Function - In commercial practice, hexachloroethane is produced by the chlorination of perchloroethylene at 100-140°C. This reaction is carried out in a lead-lined vessel in the presence of ferric chloride.

When 50-60% conversion to hexachloroethane is attained, the reaction is halted. After treatment with alkali to neutralize dissolved hydrogen chloride, the product solution is allowed to crystallize. The crystals are removed by centrifuging, and unreacted perchloroethylene is recovered and recycled to the chlorinator.

2. Input Materials

Perchloroethylene

Chlorine

Sodium hydroxide

Water

3. Operating Parameters

Temperature: 100-140°C (212-284°F)

Pressure: not given

Catalyst:  $\text{FeCl}_3$

4. Utilities

Not given

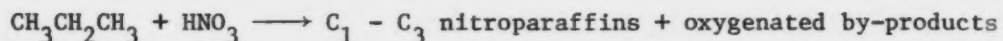


5. Waste Streams - Waste water from the purification section probably contains sodium chloride, caustic, various chlorinated by-products, and traces of perchloroethylene and hexachloroethane.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 200.

C<sub>1</sub> - C<sub>3</sub> Nitroparaffins (from propane)

1. Function - Propane is oxidized in the vapor phase with 65% nitric acid. The nitration is carried out in a silica-clad stainless steel reactor at 390-450°C and 0.8-1.2 MPa (8-12 atm). Approximately 40% of the nitric acid is converted to nitroparaffins, the remainder acts as an oxidizing agent, resulting in the oxygenated by-products, and is reduced to nitric oxide (NO). This is reoxidized to nitrogen dioxide which is utilized to produce additional nitroparaffins. The combined yield of HNO<sub>3</sub> to organic nitrates is 90%.

The temperature affects the reaction rate of reaction, the product composition (high temperature favors 1-nitro compounds), and the yield of oxidation products. High pressure increases rate but not product composition. The yield of nitromethane and 2-nitropropane may be increased at the expense of the other nitroalkanes by the use of 0.03-0.2 moles of an oxygenated sulfur compound.

The nitroalkanes, aldehydes and ketones are condensed leaving unreacted propane and nitric oxide in the gas phase. Propane is separated and recycled, the NO is oxidized with air to NO<sub>2</sub> which is absorbed in water to produce HNO<sub>3</sub>. This nitric acid solution is brought up to strength by the addition of concentrated HNO<sub>3</sub> and returned to the process. The aldehydes and ketones are separated from the nitroalkanes by solvent extraction with chlorinated aromatics. The nitroalkanes are separated and purified by fractional distillation.

2. Input Materials

Propane - 0.68 - 0.91 kg/kg product

Nitric acid - 0.98 - 1.30 kg/kg product

Water

Air

3. Operating Parameters

Temperature: 370-450°C (698-842°F)

Pressure: 0.8-1.2 MPa (8-12 atm)

4. Utilities

Not given

5. Waste Streams - Waste water from washing operations probably contains a number of by-product aldehydes, ketones, acids, alcohols, and olefins. These same pollutants plus carbon monoxide, NO<sub>x</sub>, and propane may be present in waste gases from separators and other purification equipment.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 873-874.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 546-550.

n-Butenes (dehydration of n-butane)

1. Function - In the Phillips process, n-butenes are produced by the dehydrogenation of n-butane to serve as intermediates en route to butadiene.\* The feed, preferably 98% n-butane, is dried carefully over bauxite and charged to externally heated tubular reactors filled with alumina-chromia catalyst. The dehydrogenation is carried out at 566-593°C and 108-239 kPa (1-20 psig) with 30% n-butane conversion per pass and 80% selectivity to n-butenes. The process operates cyclically, alternate reactors being used one hour for dehydrogenation and one hour for catalyst regeneration.\*\*

Hydrogen, C<sub>1</sub> - C<sub>3</sub> hydrocarbons, and other conversion by-products are separated from the reactor effluent by fractionation. The remaining C<sub>4</sub> hydrocarbon mixture is separated by extractive distillation with aqueous furfural or acetonitrile in two fifty-plate columns. Unreacted n-butane is collected overhead, washed with water, and recycled. The n-butenes remain in the solvent bottoms, from which they are separated by subsequent distillation and washed with water. Recovery of n-butenes as a 90-95% concentrate usually runs on the order of 80-90%.

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\* n-Butenes produced by this process may also be used in the preparation of other derivatives.

\*\* This is carried out at 791 kPa (100 psig) with an air-flue gas mixture containing 2-3% oxygen.

2. Input Materials

n-Butane (98%) - 1.44-1.62 kg/kg product

Furfural or acetonitrile

Water

3. Operating Parameters

Temperature: 566-593°C (1050-1099°F)

Pressure: 108-239 kPa (1-2.3 atm)

Catalyst: alumina-chromia

Space Velocity: 700

4. Utilities - Not given

5. Waste Streams - Furfural or acetonitrile and various C<sub>4</sub> hydrocarbons are probably present in air and wastewater emissions from extractive distillation and washing operations. Quench waters from the dehydrogenation section may also contain C<sub>4</sub> hydrocarbons as well as residue gas, tars, and oils.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 834.

Friedman, L., Womeldorph, D.E. and Stevenson, D. H., Proc. Am. Petrol. Inst., Sec. III, 38, 202-218, 1958.

Polybutenes

1. Function - Commercial polybutenes are viscous, tacky liquids with molecular weights ranging from 300-3,000. They are produced by the aluminum chloride-catalyzed polymerization of dried, desulfurized butane/butylenes refinery streams obtained from catalytic or thermal cracking operations. The isobutylene in the feed is polymerized to the greatest extent, so the product is composed predominantly of polyisobutylenes with indeterminate but minor quantities of poly(n-butenes) and insignificant amounts of n- and isobutane.

The yield of polybutenes from this process is about 83%, based on butylene feedstock. Unreacted butanes and the butylenes may be recycled or returned to the refinery.

2. Input Materials

Butane/butylenes refinery stream butylenes - 1.2 kg/kg product

3. Operating Parameters

Temperature - Not given

Pressure - Not given

Catalyst -  $\text{AlCl}_3$

4. Utilities - Not given

5. Waste Streams - Air emissions from this process may contain quantities of  $\text{C}_4$  hydrocarbons, dimers, trimers, etc., and polymerization solvents, i.e., alcohols, ethers, alkyl halides. Spent  $\text{AlCl}_3$  catalyst and reaction by-products may be present in solid or liquid process wastes. However, no specific information was available.

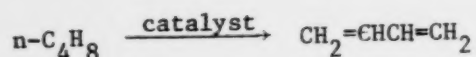
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience  
Publishers, New York, N.Y., Vol. 3 (1964), p. 946-55.

Ibid., Vol. 14 (1967).



Butadiene (oxidative dehydrogenation of n-butenes)

1. Function - Since 1971, the Phillips process has employed an oxidative dehydrogenation in the production of butadiene from n-butenes. In this process, a compressed air/steam mixture is heated, mixed with n-butene, and passed over the oxidative dehydrogenation catalyst.

The C<sub>4</sub> components are recovered and the butadiene is extracted and purified by the methods described in Process No. 59.

The significant attribute of this process is the savings in fuel: oxidative dehydrogenation is an exothermic rather than an endothermic process, and so requires significantly less energy than other dehydrogenation processes.

2. Input Materials

n-Butenes - (90-95%)

Air - 10% of butylene feed

Water - (18 vols/vol butadiene)

Hydrogen - (acetylenics removal)

Furfural or acetonitrile

3. Operating Parameters

Temperature - 620-675°C (1148-1247°F)

Pressure - low partial pressures

Space velocity - 400 vols/hr per volume catalyst

Catalyst - Ca, Ni, PO<sub>4</sub>

4. Utilities - Not given

5. Waste Streams - Waste flows from butadiene production facilities were 417 m<sup>3</sup>/Gg (100 gal/ton) of product.

The principal pollutant sources should be the quench waters containing tars, oils and soluble hydrocarbons and the solvent extract and wash waters (if acetonitrile or furfural is used) containing acetonitrile, furfural and C<sub>4</sub> hydrocarbons. Some air emissions of furfural or acetonitrile may also occur.

pH: 8-9

TOC: 100-200 g/m<sup>3</sup>

Filtered COD: 250-375 g/m<sup>3</sup>

Suspended solids: 200-500 g/m<sup>3</sup>

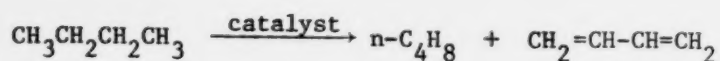
Total solids: 3-4 kg/m<sup>3</sup>

6. EPA Source Classification Code - None

7. References

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, pp. 164-167.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Murray Ltd., London, 1973, pp. 156-157.

Butadiene (Houdry process)

1. Function - In the Houdry process, 95+% n-butane is dehydrogenated in one step to a mixture of butenes and butadiene. Fresh feed and recycle  $\text{C}_4$  hydrocarbons are preheated to 593°C and passed over an activated alumina catalyst bed impregnated with 18-20% chromic oxide. The reactors are brick-lined horizontal drums operating at pressures of 13.8-20.7 kPa (0.14-0.2 atm) and a space velocity of about 2 (liquid volume of feed per hour per volume of catalyst space).

Butadiene is separated from the reactor effluent by the methods described in Process No. 59, and unreacted butane and butenes are recycled. Depending on economic considerations, Houdry units can be run to maximize production of butadiene or butenes. Maximum production of butadiene corresponds to a yield of 57-63%.

2. Input Materials

n-Butane (95+) - 1.7-1.9 kg/kg butadiene

Hydrogen (acetylenics removal)

Furfural or acetonitrile

3. Operating Parameters

Temperature - 593°C (1099°F)

Pressure - 13.8 - 20.7 kPa (0.14-.20 atm)

Catalyst - alumina with 18-20% chromic oxide

Space Velocity - 2 (see above)

4. Utilities - Not given

5. Waste Streams - A typical waste water flow from a butadiene production facility was  $417 \text{ m}^3/\text{Gg}$  (100 gal/ton) of product.

The principal sources of pollutants should be the quench waters containing tars, oils, and soluble hydrocarbons and the solvent extract and wash waters (if acetonitrile or furfural are used as extractants) containing acetonitrile or furfural and  $\text{C}_4$  hydrocarbons. Some air emissions of furfural or acetonitrile may also occur.

TOC:  $100\text{--}200 \text{ g/m}^3$

Filtered COD:  $250\text{--}375 \text{ g/m}^3$

Suspended solids:  $200\text{--}500 \text{ g/m}^3$

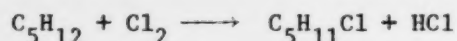
Total solids:  $3\text{--}4 \text{ kg/m}^3$

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 800.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley & Sons, New York, N.Y., 1975, p. 167-168.

Amyl Chlorides (from pentane/isopentane)

1. Function - Mixtures of isomeric amyl chloride are produced by the continuous vapor-phase chlorination of a n-pentane-isopentane refinery cut. In this process, the pentane feed is dried with hydrogen chloride to prevent corrosion of the steel equipment, combined in excess with chlorine gas, and passed through a heated pipe still. Conversion takes place in the absence of light and catalysts.

The mixed vapors from the reactor are cooled rapidly and passed through a series of four continuous fractionation columns. Hydrogen chloride and most of the pentane are stripped in the first two columns. Amyl chloride is taken overhead and polychloropentanes from the bottom of the third column. Any residual pentane is removed from the amyl chloride in the fourth column. With additional equipment, dichloropentane may be isolated from the polychloropentane mixture as a saleable by-product.

2. Input Materials

Pentane/isopentane

Chlorine

3. Operating Parameters - Not given

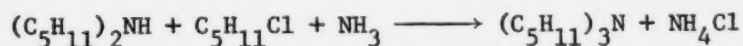
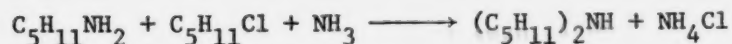
4. Utilities - Not given

5. Waste Streams - Process leaks may result in the discharge of hydrogen chloride, chlorine, pentanes, and various  $\text{C}_5$  chlorohydrocarbons to the atmosphere. No specific information was available.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Ed., Interscience  
Publishers, New York, N.Y., Vol. 2 (1963), p. 375.

Amyl Amines (from amyl chloride)

1. Function - One commercial route to amyl amines involves the reaction of ammonia and amyl chloride.

As in all reactions between ammonia and alkyl halides, quantities of di- and tri- substituted amines are also formed.

2. Input Materials

Amyl chloride

Ammonia

3. Operating Parameters

Not given

4. Utilities

Not given

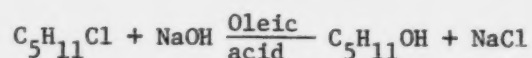
5. Waste Streams - Effluents from the ammonia stripper may contain amyl chloride, ammonia, and various amyl amines. Ammonium chloride and heavier organics are probably present in some waste stream from the purification section, but no specific information was available.

6. EPA Source Classification Code - None



7. References

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Co., New York, N. Y., 1956 , p. 245.

Amyl Alcohols (from amyl chlorides)

1. Function - Isomeric amyl alcohols are produced by the high-temperature hydrolysis of mixed amyl chlorides. This continuous hydrolysis is carried out with aqueous sodium hydroxide in the presence of sodium oleate catalyst. In most process variations, the reaction slurry is passed through two digesters. Amyl alcohols, pentylenes, chlorides, and minor amounts of amyl ether distill overhead from the second digester and brine is drawn from the bottom. The remaining slurry is recycled to the first digester so that the initial charge of oleic acid, which is converted to sodium oleate, does not need constant replenishment.

Pentylenes and unreacted amyl chlorides are stripped from the alcohol by steam distillation, and the chlorides are recycled. The alcohol is fractionated into commercial compositions and sold along with the pentylene and amyl ether by-products.

2. Input Materials

Amyl chlorides, mixed

Sodium hydroxide

Water

Oleic acid

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst: oleic acid

4. Utilities

Not given

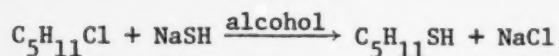
5. Waste Streams - The principal pollutant source in this process is probably the waste water from the brine decanter, containing sodium chloride, sodium hydroxide, and traces of amyl alcohols, amyl chlorides, pentylenes, and amyl ether. All of these organics may also be present in the waste water from the amyl alcohol recovery column.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963) p. 375.

Amyl Mercaptans (from amyl chloride)



1. Function - A mixture of isomeric amyl mercaptans is produced by the interaction of amyl chloride and sodium or potassium hydrosulfide in alcohol.
2. Input Materials  
Amyl chloride  
Sodium or potassium hydrosulfide  
Solvent alcohol
3. Operating Parameters  
Not given
4. Utilities  
Not given
5. Waste Streams - Indeterminate quantities of sodium or potassium chloride, amyl chloride, amyl mercaptans, sodium or potassium hydrosulfide, the solvent alcohol, and reaction by-products such as diamyl sulfide may be present in process wastes.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 20 (1969), p. 212-13.  
Ibid., Vol. 2 (1963), p. 375.

Isoamylenes (from C<sub>5</sub> hydrocarbons)

1. Function - Isoamylenes (2-methyl-1-butene and 2-methyl-2-butene) are extracted from a catalytically cracked C<sub>5</sub> gasoline stream with 65% aqueous sulfuric acid. This extraction is carried out in multiple absorption stages at temperatures of 0-10°C.

The isoamyl alcohols formed dissolve in the aqueous phase and are washed with caustic and water to remove residual acid. This aqueous phase is separated and contacted with hexane or a similar solvent at 50°C to reconvert the isoamyl alcohols to isoamylenes. After caustic and water washings, hexane is stripped from the solution to recover the isoamylene concentrate. Recovery from the C<sub>5</sub> hydrocarbon feed is about 22.5%.<sup>\*</sup> However, this figure may be as low as 7.5%, depending on the amylene concentration of the feed.

2. Input Materials<sup>\*\*</sup>

C<sub>5</sub> hydrocarbons - 3.72 kg/kg isoprene

Sulfuric acid - 8.50 kg/Mg isoprene

Sodium hydroxide - 10.0 kg/Mg isoprene

Hexane - 31.5 kg/Mg isoprene

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<sup>\*</sup>The C<sub>5</sub> hydrocarbons feedstocks usually contain about 30% isoamylene by weight, but concentrations may be as low as 10%. About 75% of the isoamylene in the feed is recovered.

<sup>\*\*</sup>The data given is based on isoprene production for which the isoamylene serves as an intermediate.

3. Operating Parameters

Temperature - extraction - 0-10°C (32-50°F)  
Hexane treatment - 50°C (122°F)

Pressure - not given

4. Utilities - see Process Nos. 235 and 236.

5. Waste Streams<sup>\*\*</sup>

Amylene recovery section - separation vessel (water)

Sodium hydroxide - 3.05 kg/Mg isoprene

Sodium sulfate - 14.0 kg/Mg isoprene

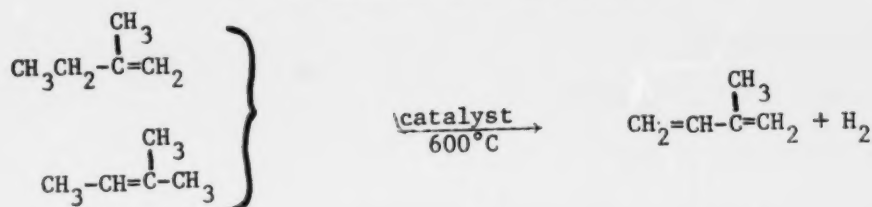
Amylene recovery section - amylene recovery column (water)

n-Hexane - 19.0 kg/Mg isoprene

6. EPA Source Classification Code - None

7. References

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1973,  
p. 101.

Isoprene (from isoamylenes)

1. Function - One of the most popular routes to isoprene involves the dehydrogenation of isoamylenes extracted from  $\text{C}_5$  gasoline (see Process No. 246). In this process, the amylene feed and a  $\text{C}_5$  recycle stream from a downstream purification unit are mixed with steam passed to a catalytic reactor operating at  $600^\circ\text{C}$  and atmospheric pressure. A mixture of iron oxide,  $\text{K}_2\text{CO}_3$ , and  $\text{Cr}_2\text{O}_3$  catalyzes the conversion to isoprene with by-production of hydrogen, carbon dioxide, and a variety of  $\text{C}_2 - \text{C}_5$  hydrocarbons.

The  $\text{C}_4$  and  $\text{C}_5$  hydrocarbons are recovered from the reactor effluent in an absorber-stripper section. The dry gas from the absorber usually serves as fuel gas, typically containing: hydrogen, methane, ethylene, ethane, propylene, propane, butylene, butane, butadiene, isoprene, t-amylenes, piperylenes, other  $\text{C}_5$ 's and absorber oil. Approximately 322 kg of fuel gas are produced per Mg of isoprene.

Upon leaving the stripper, the overhead product is processed for light ends removal. The light ends (mainly  $\text{C}_4$ 's) are fed to a debutanizer which recovers the  $\text{C}_4$  fraction overhead for use as fuel gas and a bottom product for recycle to the reactor. The bottom product of the light ends column is the crude isoprene, which is fed to a Shell Acetonitrile process unit for purification.



2. Input Materials

Isoamylenes - see Process No. 246.

3. Operating Parameters

Temperature - 600°C (1112°F)

Pressure - 100 kPa (1 atm)

Catalyst - iron oxide,  $K_2CO_3$ ,  $Cr_2O_3$  mixture

4. Utilities\* - basis: 1.15 kg/sec capacity (80 M lb/yr)

Cooling water - 1.05 m<sup>3</sup>/sec (1.0 M gph)

Process water - 16.0 dm<sup>3</sup>/sec (15,200 gph)

Steam - 6.36 kg/sec (50,500 lb/hr)

Electrical power - 9.72 EJ (2.7 MW)

Fuel - 2.16 m<sup>3</sup>/sec (275,000 cft)

5. Waste Streams

Dehydrogenation section - partial condensers (water)

Isoprene - 0.5 kg/Mg product

Amylenes - 1.5 kg/Mg product

Isoprene recovery section - extractive distillation column (air)

Acetonitrile - 5.0 kg/Mg product

6. EPA Source Classification Code - None

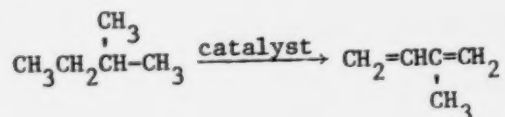
7. References

"1973 Petrochemical Handbook Issue," Hydrocarbon Processing, Nov. 1973, p. 140.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

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\* Includes utilities for isoamylenes extraction--Process No. 247.

Isoprene (direct dehydrogenation of isopentane)

1. Function - A promising, new route to isoprene involves a single-step, fixed-bed dehydrogenation of isopentane or a C<sub>5</sub> fraction obtained by catalytic cracking. In this process, fresh C<sub>5</sub> feedstock is combined with recycle from the isoprene recovery section and heated to 540-620°C. The dehydrogenation takes place over a chromia-alumina catalyst in a cyclic series of three reactors operating at 74-81 kPa (0.7-0.8 atm) partial vacuum.

The product stream is quenched by direct contact with a quench oil stream and compressed before passing into the recovery section. In the recovery section, a conventional absorber, stripper, and debutanizer system recovers the C<sub>5</sub> compounds which are then charged to the isoprene purification section. The purification section (Shell acetonitrile process) gives isoprene product (99% + pure), 1,3-pentadiene, and recycled isopentane-pentylenes.

This process had been used for the manufacture of isoprene only on a pilot plant scale. Yields of 51.5% based on isopentane and 58.6% based on a C<sub>5</sub> gasoline fraction have been reported.

2. Input Materials

C<sub>5</sub> hydrocarbons

Isopentane - 2.06 kg/kg isoprene

C<sub>5</sub> gasoline fraction - 1.76 kg/kg isoprene

3. Operating Parameters

Temperature: 540-620°C (1004-1148°F)

Pressure: 74-81 kPa (0.72-0.81 atm)

Catalyst: chromia-alumina

Space velocity: 1.5-3.5 hr<sup>-1</sup>

4. Utilities

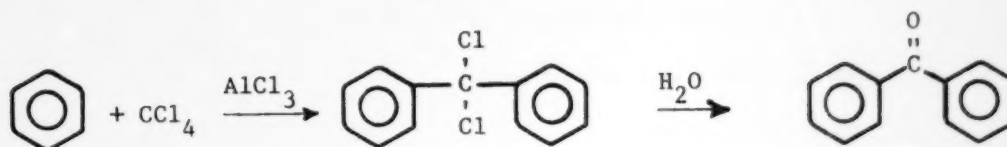
Not given

5. Waste Streams - Generally, the same types of pollution would be expected as in Process No. 247.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 75.

Benzophenone

1. Function - Benzophenone is manufactured principally by the Friedel-Crafts reaction of benzene and carbon tetrachloride. Carbon tetrachloride and anhydrous aluminum chloride are charged to a jacketed agitated, iron vessel and thiophene-free benzene is fed in over a period of three to five hours with cooling. The hydrogen chloride evolved is removed by an absorption tower that is coupled with a settling tank where carbon tetrachloride is recovered.

The temperature of the mixture is allowed to rise to 35°C (95°F) for 0.5 hour after the benzene has been added. The viscous mass is transferred to a still containing water, heated to boil with a steam injector, and held at that temperature by the heat of reaction. The vapors are fed to the absorption system mentioned above.

The crude benzophenone is vacuum distilled and crystallized from a solvent.

2. Input Materials - Basis: 113.4 kg (250 lb) batch

Benzene - 115.7 kg (255 lb)

Carbon tetrachloride - 476 kg (1,050 lb)

Aluminum chloride - 104.3 kg (230 lb)

Water (hydrolysis) - 378.5 dm<sup>3</sup> (100 gal)

3. Operating Parameters

Temperature: reaction - 20°C (68°F)  
                  final reaction - 35°C (95°F)

Equipment: jacketed, iron reactor

4. Utilities - Not given

5. Waste Streams

Water: Waste streams may contain some acid, small amounts of carbon tetrachloride, some aromatic residues, aluminum chloride hydrolysis products.

Solids: Aluminum hydroxide by hydrolysis of aluminum chloride-aromatic complexes, tars from still bottoms, and still bottoms from recovery of recrystallizing solvent.

Air: Possible hydrogen chloride vapors.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 3 (1964), p. 439-444.

SECTION VIII  
PROPYLENE

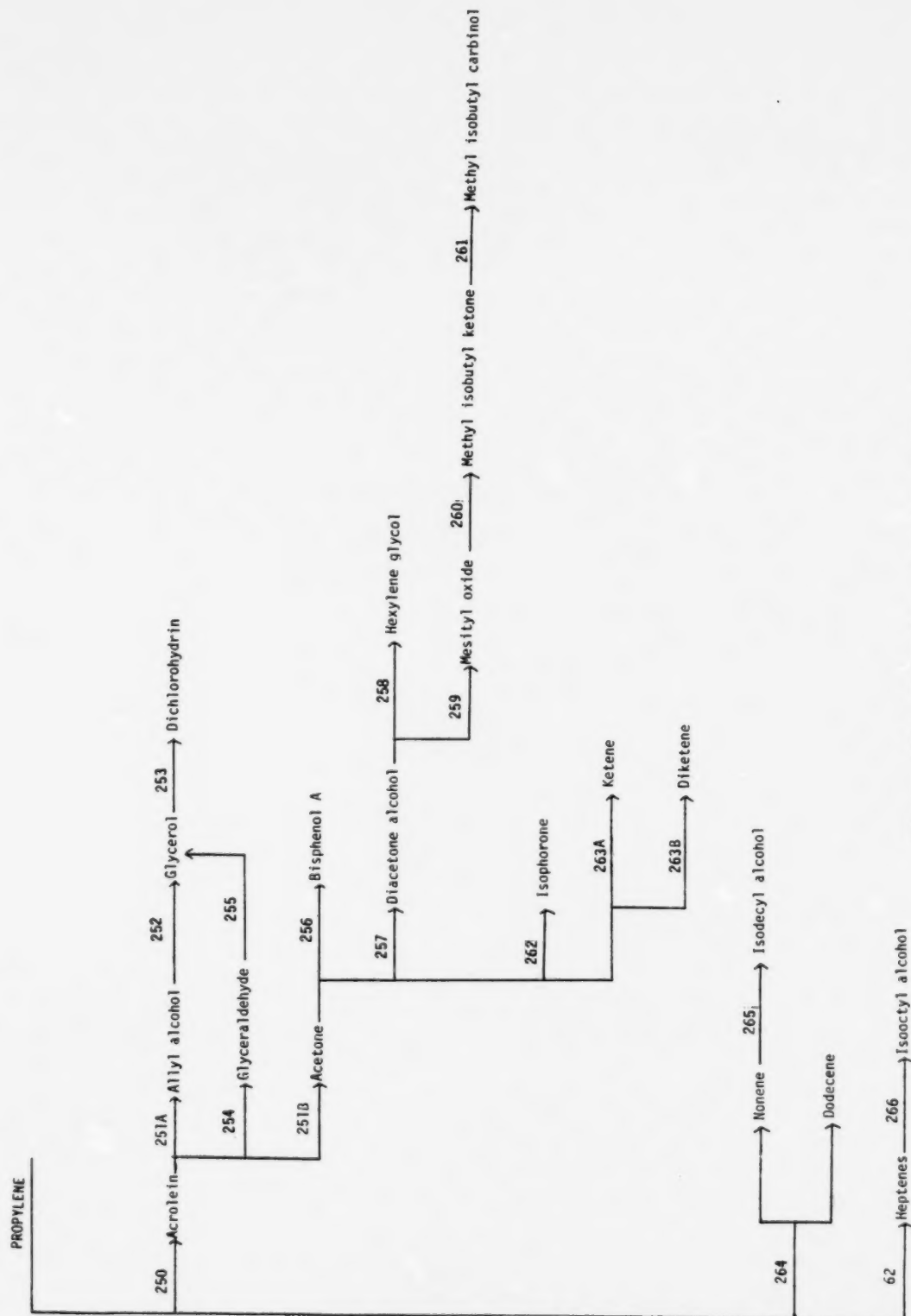


Figure 15. Propylene Section Chemical Tree



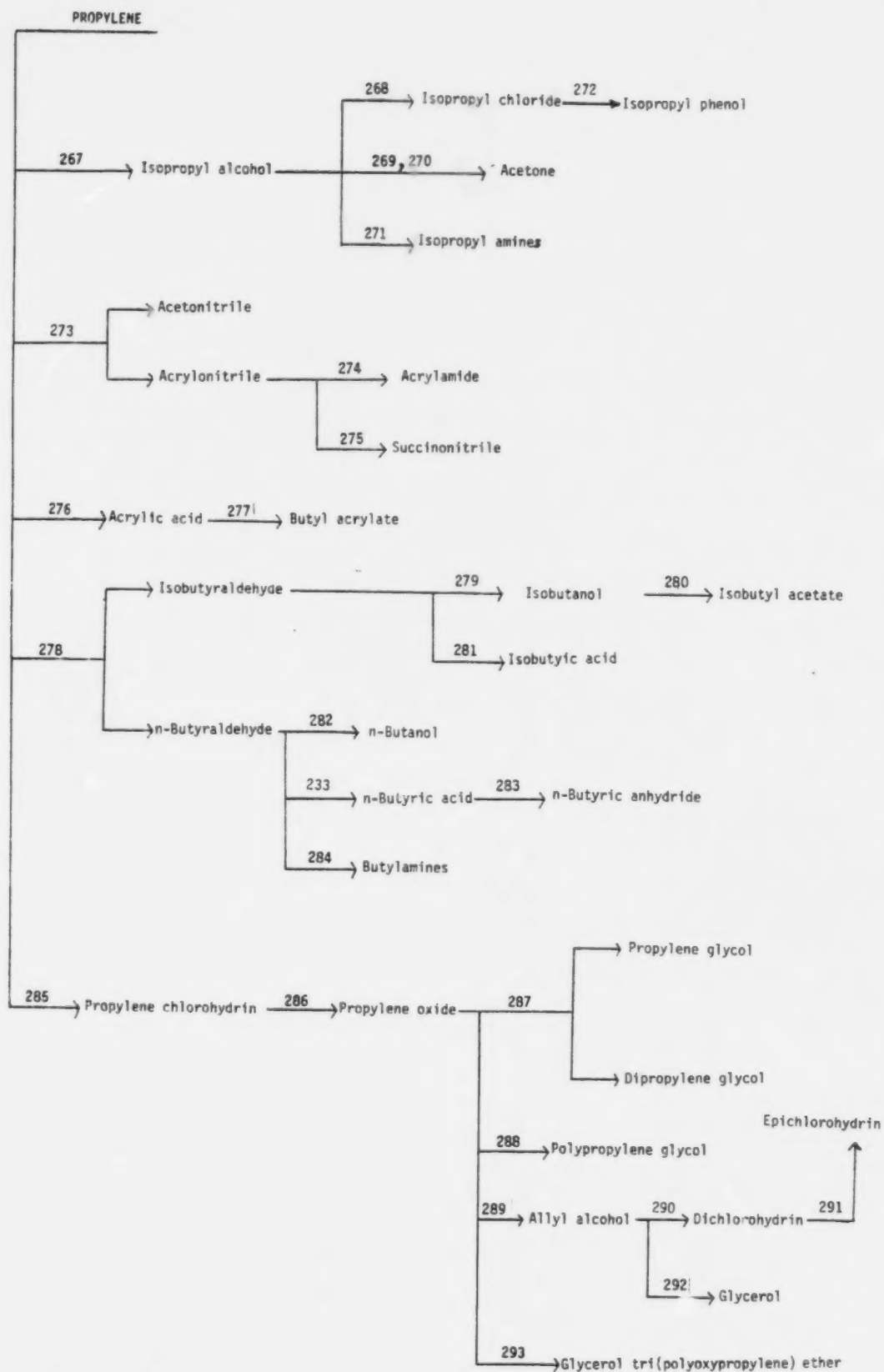


Figure 15. Propylene Section Chemical Tree (Cont.)

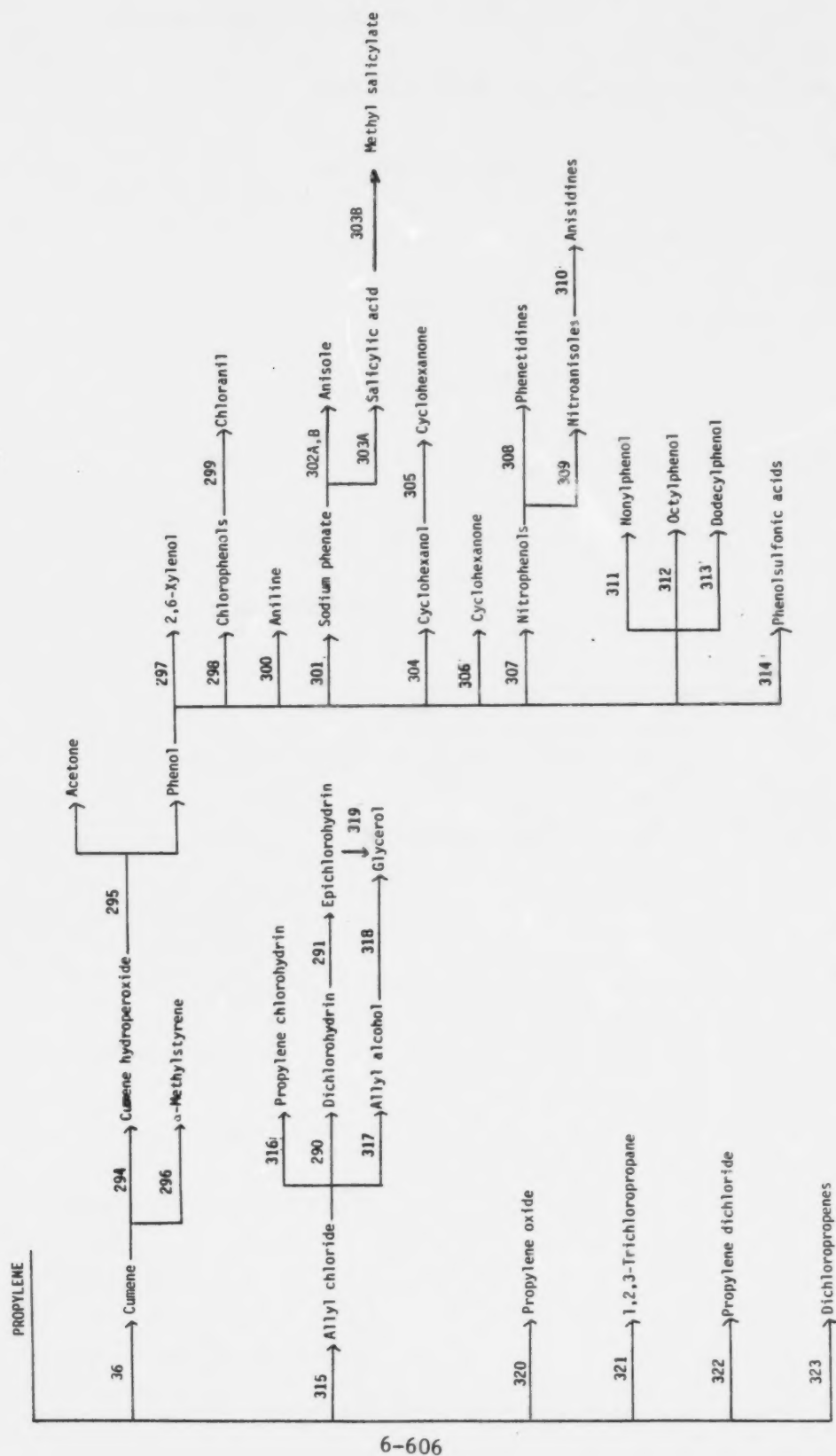


Figure 15. Propylene Section Chemical Tree (Cont.)

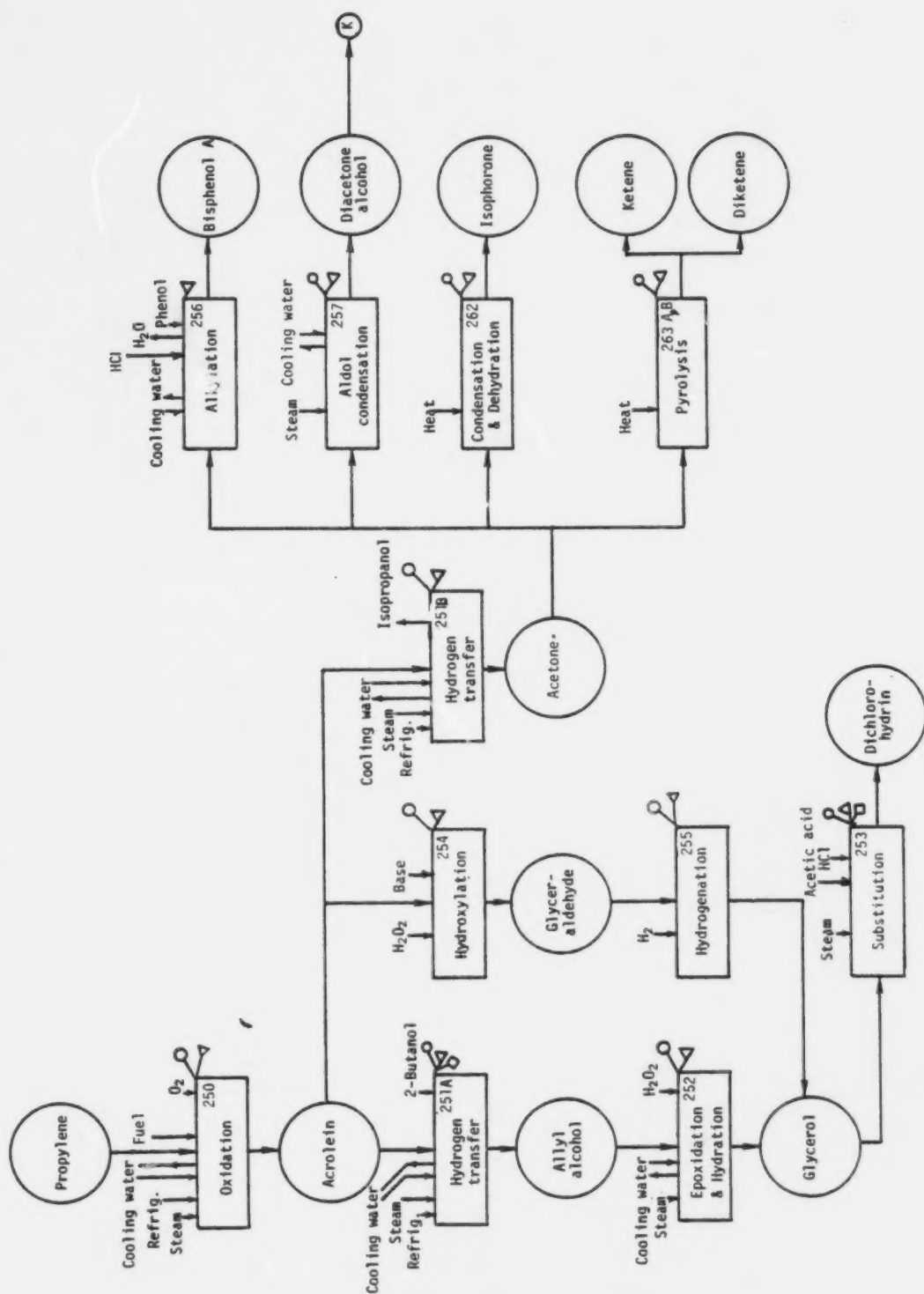


Figure 16. Propylene Section Process Flow Sheet

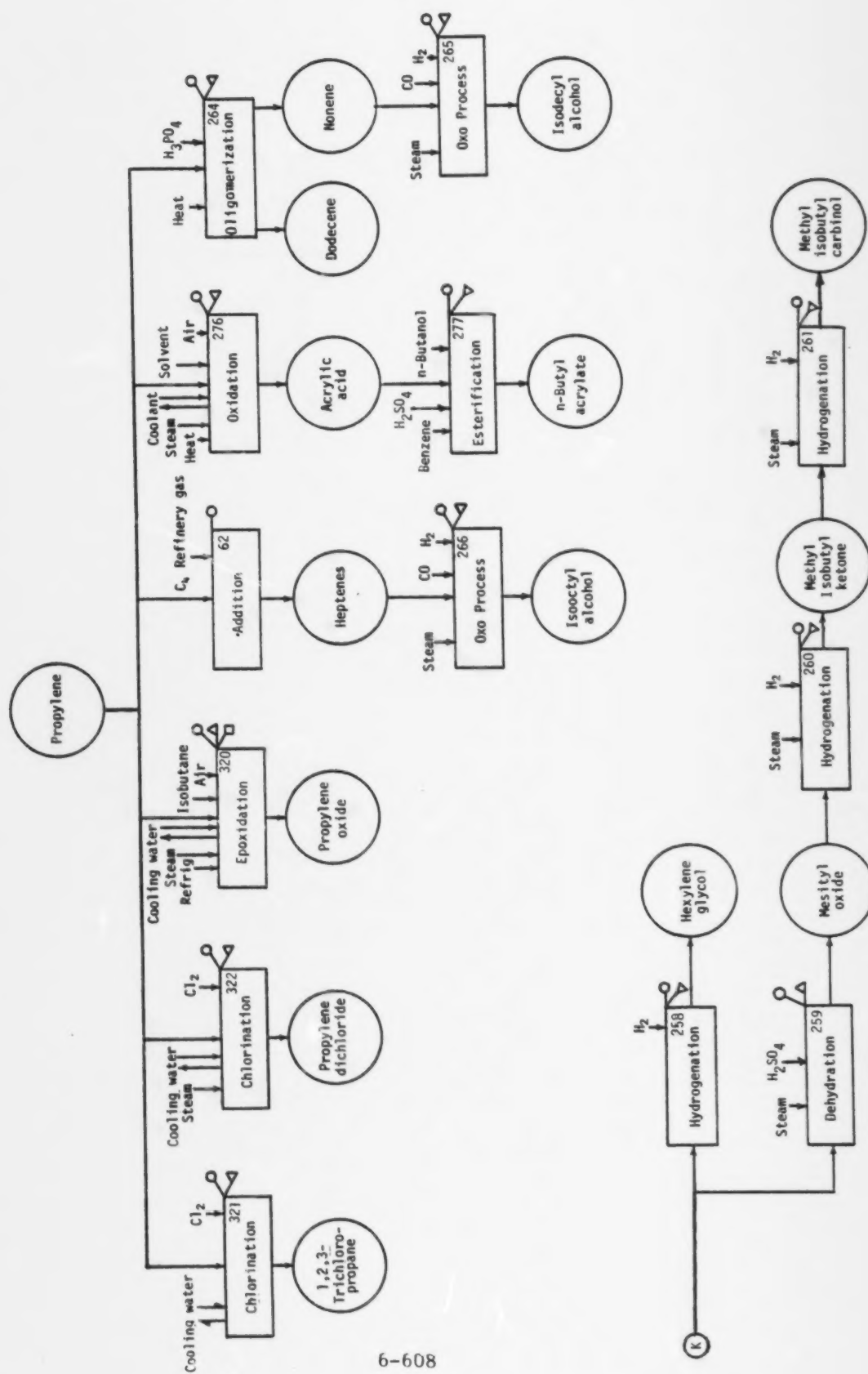


Figure 16. Propylene Section Process Flow Sheet (Cont.)

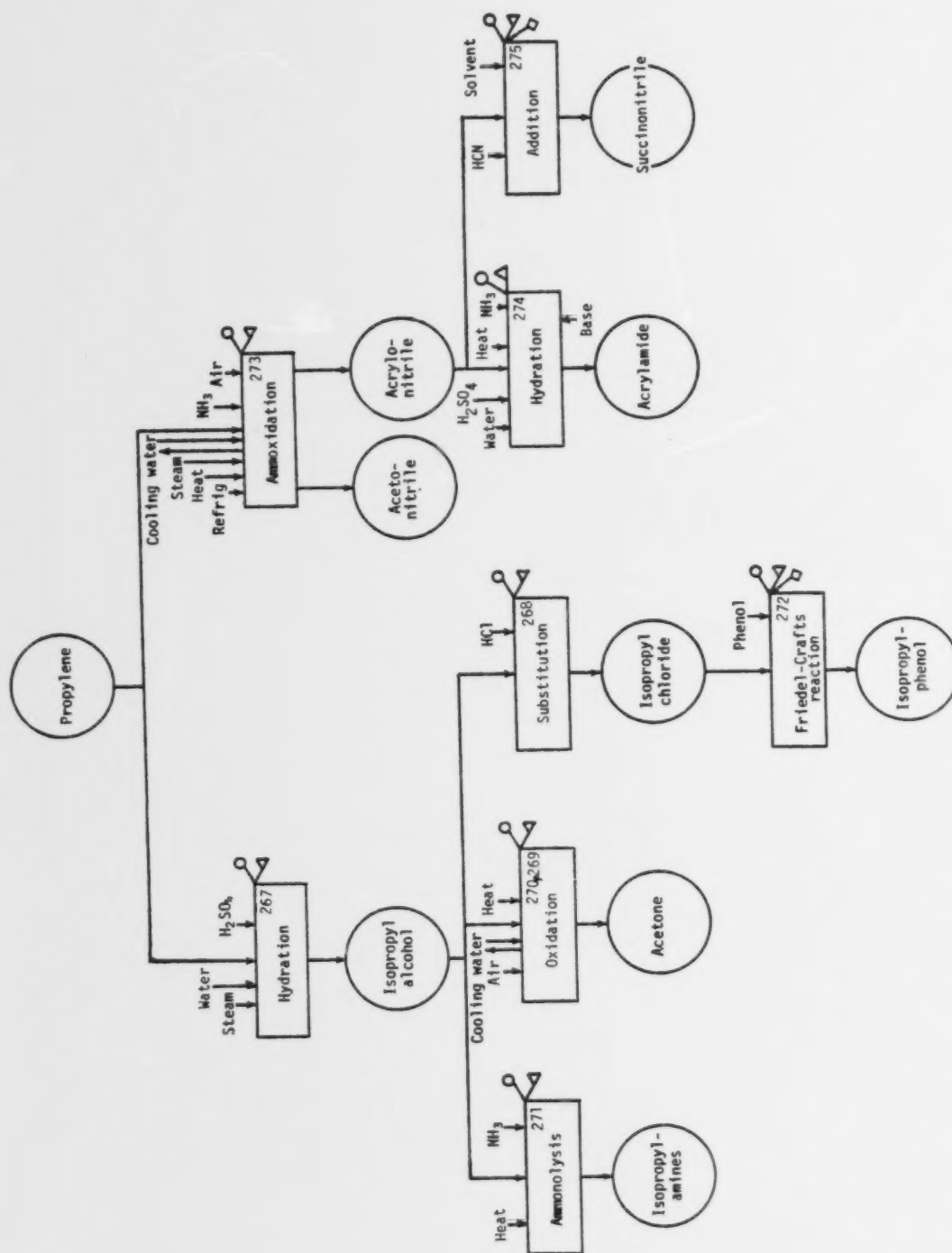


Figure 16. Propylene Section Process Flow Sheet (Cont.)

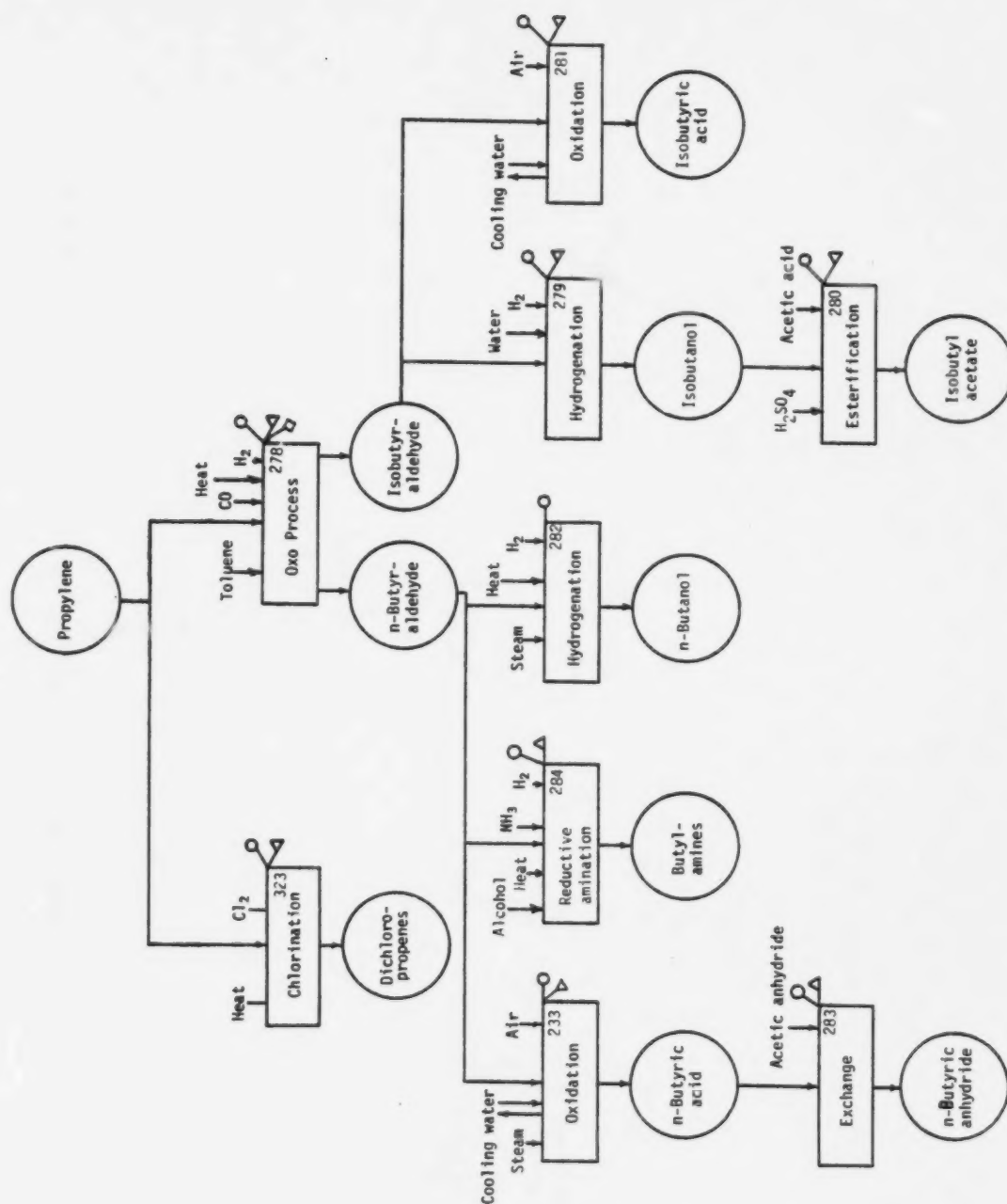


Figure 16. Propylene Section Process Flow Sheet (Cont.)

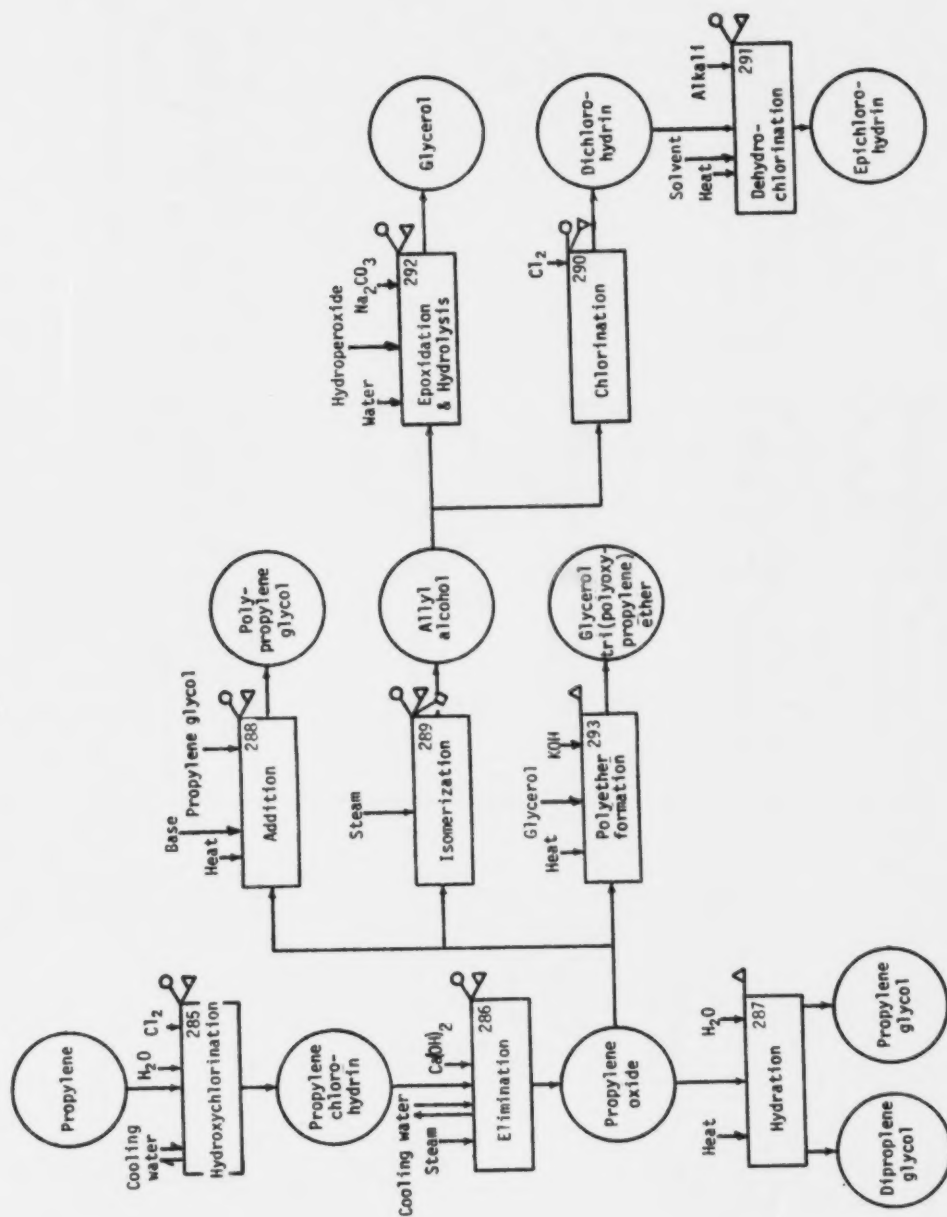


Figure 16. Propylene Section Process Flow Sheet (Cont.)



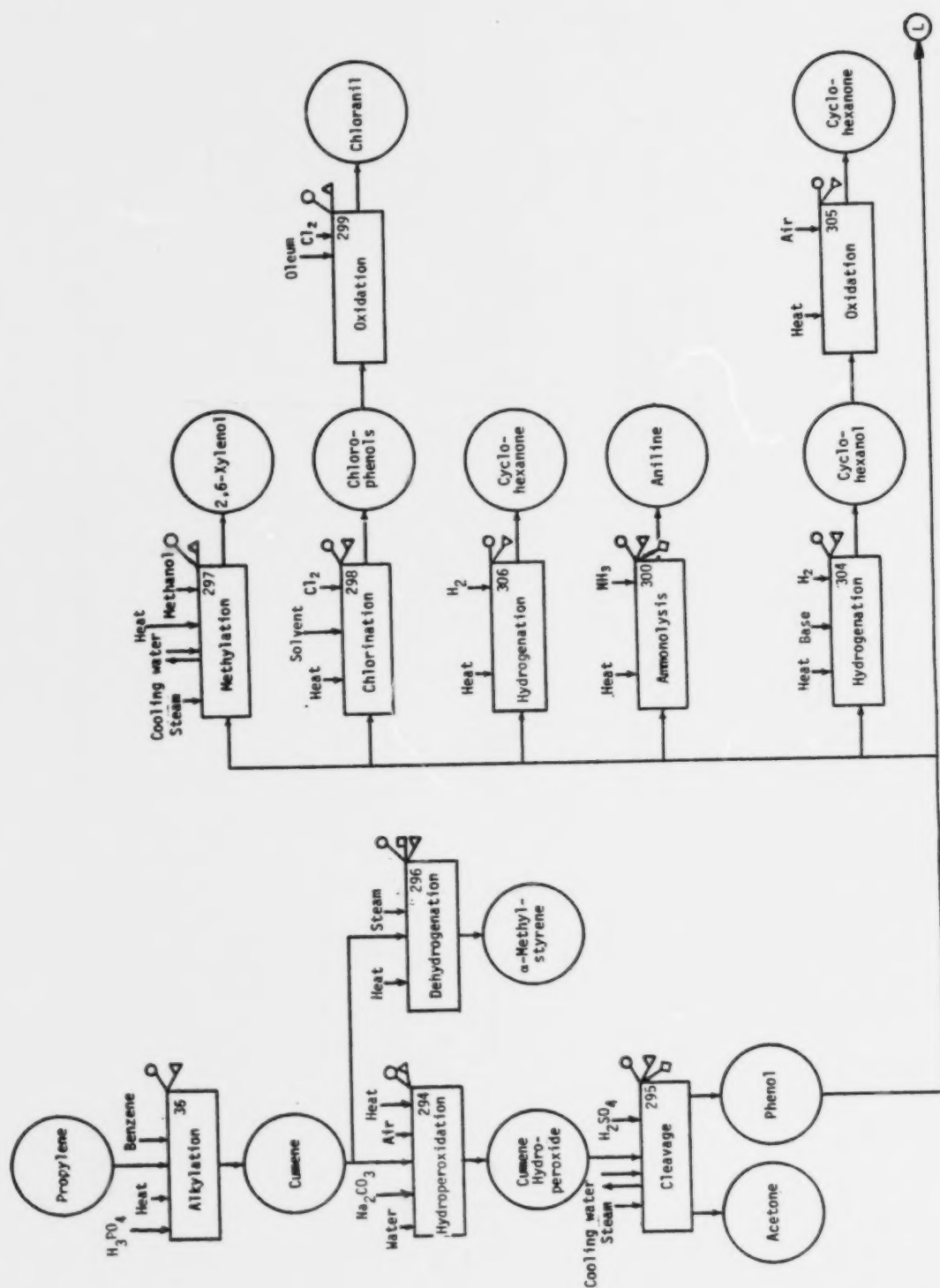


Figure 16. Propylene Section Process Flow Sheet (Cont..)

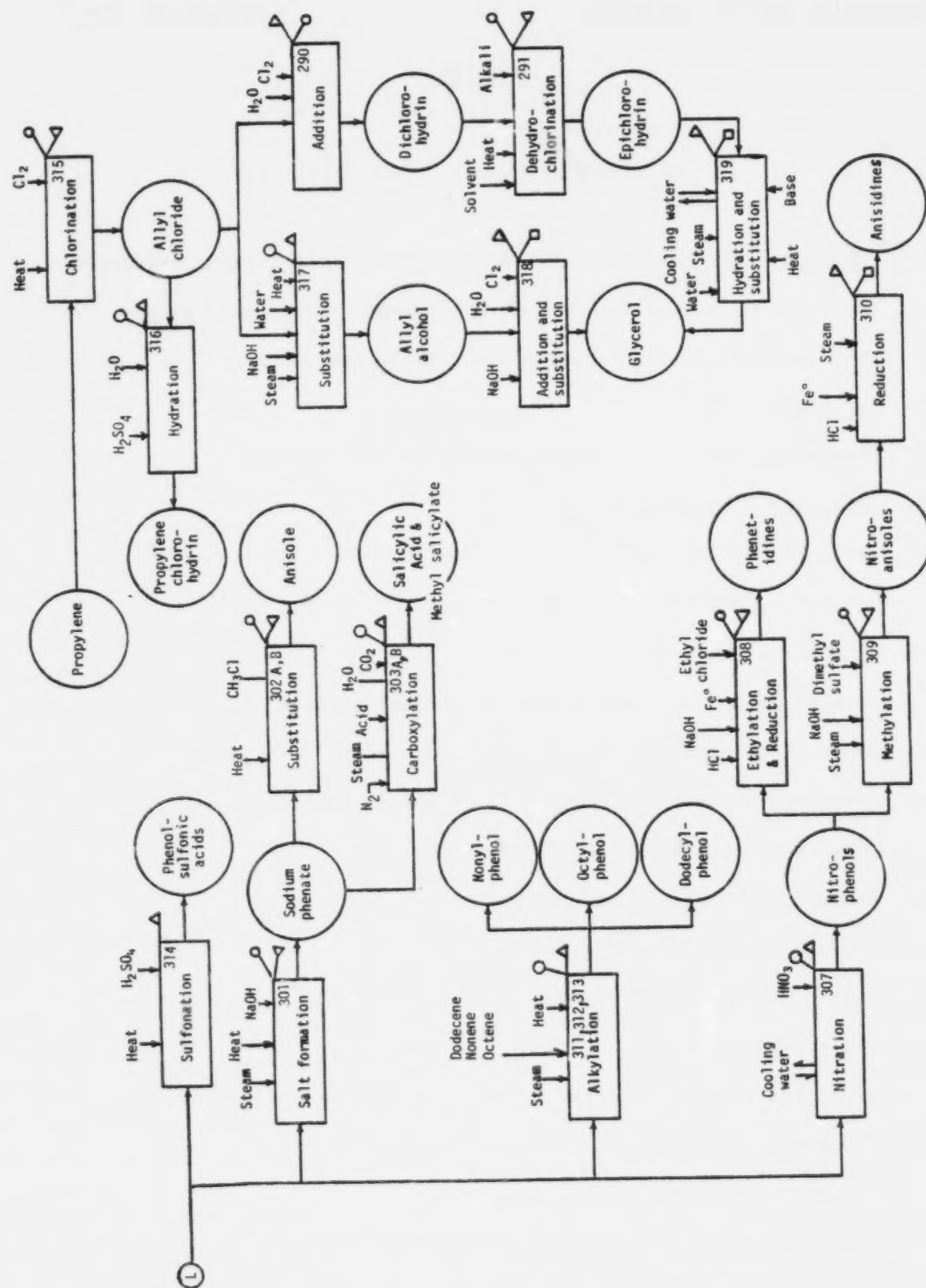


Figure 16. Propylene Section Process Flow Sheet (Cont.)

Acrolein

1. Function - Acrolein is produced by a limited vapor-phase oxidation of propylene in the presence of a catalyst. Oxygenated by-products complicate the product recovery and purification.
2. Input Materials  
Propylene (98%) - 1.161 Mg/Mg (2,322 lb/ton) product
3. Operating Parameters  
Temperature - 290-380°C (550-720°F)  
Pressure - 410-580 kPa (4.05-5.72 atm)  
Flow rates - not given  
Size of equipment - not given - fixed bed reactor  
Types of catalysts - copper-oxide and bismuth-molybdenum
4. Utilities - Basis - 9.1 Gg/yr (20 M lb/yr) capacity  
Cooling water - 378 dm<sup>3</sup>/s (6,000 gpm)  
Steam - 4.1 Mg/hr (9,100 lb/hr)  
Power - 12.3 GJ (3,430 kWh)  
Fuel - 350 kW (1.2 M Btu/hr)
5. Waste Streams  
Propylene recovery section - propylene absorber off-gas  
Propylene - 71 kg/Mg (142 lb/ton) product  
Propane - 3.5 kg/Mg (7 lb/ton) product  
Carbon monoxide - 73.5 kg/Mg (147 lb/ton) product

6. EPA Source Classification Code - None

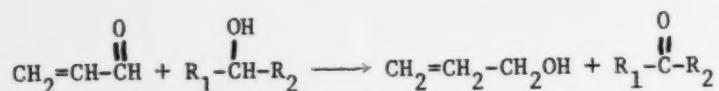
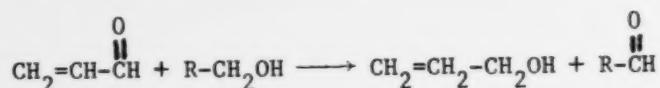
7. References

Muller, R. G., "Glycerine and Intermediates," Report No. 53,  
Stanford Research Institute, Menlo Park, California, 1969.

U. S. Patent 2,451,485 and 2,846,842.

Hancock, E. G., Propylene and Its Industrial Derivatives, John Wiley  
and Sons, New York, N.Y., 1973, p. 23.

Chemical Technology, Barnes and Noble Books, New York, N.Y.,  
Vol. 4 (1972), p. 364-427.

Allyl Alcohol; Acetone (from acrolein)

1. Function - Acrolein undergoes hydrogen transfer with either a primary or secondary alcohol in the presence of a metal alkoxide catalyst to form allyl alcohol and the aldehyde or ketone that corresponds to the donor alcohol.

It is not possible for all manufacturers to use the optimum alcohol donor. Alcohols used and the corresponding by-products are: ethyl alcohol (acetaldehyde), n-propyl alcohol (propionaldehyde), isopropyl alcohol (acetone), and secondary (2-) butanol (methyl ethyl ketone). 2-Butanol is a typical example of an alcohol which gives high allyl alcohol selectivity while producing a valuable by-product.

2. Input Materials

Acrolein - 1.044 Mg/Mg (2,088 lb/ton) product

2-butanol - 1.310 Mg/Mg (2,621 lb/ton) product

3. Operating Parameters

Temperature - 20-80°C (68-176°F)

Pressure - 100 kPa (1 atm)

Flow rates - m.g.

Types of catalyst - aluminum alkoxides

4. Utilities - Basis: 8.7 Gg/yr (19.2 M lb/yr) capacity

Cooling water - 156 dm<sup>3</sup>/s (2,473 gpm)

Steam - 14.06 Mg/hr (31,000 lb/hr)

Power - 922 MJ (256 kWh)

Refrigeration - 29°C (-20°F) - 700 kW (2.4 M Btu/hr)

Nitrogen - 140 dm<sup>3</sup>/hr (5 scfh)

5. Waste Streams -

Product recovery and purification - light ends column (water)

Acrolein - 1.25 kg/Mg (25 lb/ton) product

Methyl ethyl ketone-- 12.5 kg/Mg (25 lb/ton) product - some 2-butanol

Product recovery and purification - heavy ends column (water)

Butanol - 7.5 kg/Mg (15 lb/ton) product

Allyl alcohol - 5 kg/Mg (10 lb/ton) product

Polymer - 53.5 kg/Mg (107 lb/ton) product

Aluminum hydroxide - 82 kg/Mg (164 lb/ton) product

Trace quantities of acrolein, hydroquinone, and methyl ethyl ketone,  
and 2-butanol

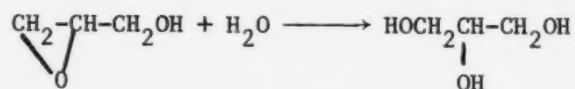
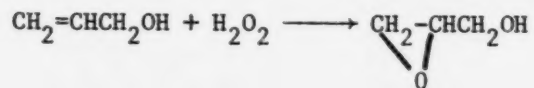
6. EPA Source Classification Code - None

7. References

Muller, K. G., "Glycerine and Intermediates," Report No. 58, Stanford  
Research Institute, Menlo Park, California, 1969.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Murray,  
London, 1973, p. 131.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4,  
(1972), pp. 287,388.

Glycerin (from allyl alcohol)

1. Function - Allyl alcohol is epoxidized with hydrogen peroxide to form glycidal which is hydrated to glycerin. The overall process may be considered a hydroxylation catalyzed by tungstic acid. The epoxidation reaction occurs in a three-section reactor maintained at 45°C for a period of 1.1 hours per section. The product glycidal is purified, then hydrated in a tubular reactor, with a 10 minute residence time, at 145°C.
2. Input Materials  
Allyl alcohol - 746.5 kg/Mg (1,493 lb/ton) product  
Hydrogen peroxide - 447 kg/Mg (894 lb/ton) product  
Caustic soda - 9 kg/Mg (18 lb/ton) product
3. Operating Parameters  
Temperature: 45°C (3-section reactor), 145°C (tubular reactor)  
Pressure: not given  
Flow rates: not given  
Size of Equipment: not given  
Types of Catalysts: tungstic acid



4. Utilities - Basis: 11.65 Gg/yr (25.7 M lb/yr) capacity

Cooling water -  $86.69 \text{ dm}^3/\text{s}$  (1,374 gpm)

Steam - 1.1 MPa (10.8 atm) - 20.487 Mg/hr (45,167 lb/hr)

380 kPa (3.75 atm) - 11.747 Mg/hr (25,898 lb/hr)

Power - 510 MJ (141 kWh)

Makeup Water -  $3.6 \text{ dm}^3/\text{s}$  (57 gpm)

5. Waste Streams

Hydroxylation section - allyl alcohol recovery column - to flare  
(air)

Allyl alcohol - 6 kg/Mg (12 lb/ton) product

Butanol - 2 kg/Mg (4 lb/ton) product

Acrolein - 20 kg/Mg (40 lb/ton) product

Miscellaneous light impurities - 22 kg/Mg (44 lb/ton) product

Glycerin recovery and purification - light ends column (water)

Allyl alcohol - 4 kg/Mg (8 lb/ton) product

Glycerin - 3.5 kg/Mg (7 lb/ton) product

Miscellaneous light impurities - 23.5 kg/Mg (47 lb/ton) product

6. EPA Source Classification Code - None

7. References

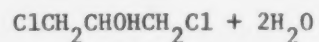
Muller, K. G., "Glycerine and Intermediates," Report No. 58,  
Stanford Research Institute, Menlo Park, California, 1969.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, John  
Wiley and Sons, New York, N.Y., 1975, p. 436.

Hancock, E. G., Propylene and Its Industrial Derivatives, John  
Wiley and Sons, New York, N.Y., 1973, p. 24-25.

Dichlorohydrin (from glycerol)

or



1. Function - In the past, dichlorohydrin has been produced by the interaction of crude glycerol and an excess of hydrogen chloride. This reaction is normally carried out at 100-160°C in a 4% solution of acetic acid.

The major by-products of this reaction are water, polyglyceride, and a mixture of acetates. Polyglyceride formation may be inhibited by lower reaction temperatures (~ 100°C), although this necessitates HCl recycling. Vacuum distillation is normally sufficient to reduce acetate production.

2. Input Materials

Glycerol - 0.79 kg/kg dichlorohydrin

Hydrogen chloride - excess

Water

3. Operating Parameters

Temperature - 100-160°C (212-320°F)

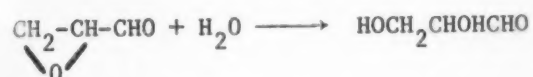
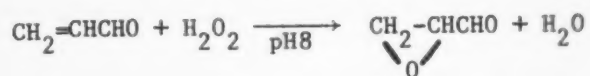
Pressure - Not given

Catalyst - acetic acid - 16 g/kg dichlorohydrin

4. Utilities - Not given

5. Waste Streams - Various waste streams may be present depending on the purification procedures employed (different reaction temperatures require different purification techniques). However, tars, acetic acid, various acetates, dichlorohydrin, and other halides from the surge-tank wastes are probably the principal pollutants.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 314.

Glyceraldehyde (from acrolein)

1. Function - Synthetic glyceraldehyde is prepared by the hydroxylation of acrolein via glycidaldehyde intermediate. If pH is maintained at 8 during the reaction, acrolein and hydrogen peroxide combine to form glycidaldehyde.

The intermediate is then hydrolyzed to give nearly quantitative yields of glyceraldehyde.

In some cases, acrolein may be converted directly to glyceraldehyde by treatment with hydrogen peroxide in the presence of  $\text{OsO}_4$  catalyst.

2. Input Materials

Acrolein - 0.65 kg/kg glyceraldehyde

Hydrogen peroxide

Water

3. Operating Parameters

Temperature - Not given

Pressure - Not given

pH - 8

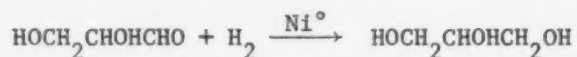
4. Utilities - Not given

5. Waste Streams - Wastewater from the separator may contain small quantities of acrolein, hydrogen peroxide, glycidaldehyde, and glyceraldehyde.

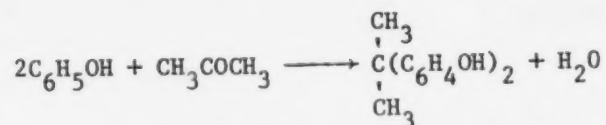
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 261.

Glycerol (hydrogenation of glyceraldehyde)

1. Function - One route to glycerol starts with propylene involving intermediates of acrolein, glycidaldehyde, and glyceraldehyde. The final intermediate, glyceraldehyde, is converted to glycerol by hydrogenation in the presence of nickel catalyst.
2. Input Materials  
Glyceraldehyde  
Hydrogen
3. Operating Parameters  
Temperature - 200°C (392°F)  
Pressure - Not given  
Catalyst - Nickel
4. Utilities - Not given
5. Waste Streams - Air vent streams would contain hydrogen gas. Purification by vacuum distillation separates glyceraldehyde and glycerol. Vents from purification system contain glycerol, waste water streams would contain glycerol and some glyceraldehyde. Because of the low vapor pressures of the reactants and products the process should be essentially free of air pollution.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 261-262.

Bisphenol-A (from phenol & acetone)

1. Function - 2,2-Bis(4-hydroxyphenyl)propane, also known as bisphenol-A, is produced by reacting phenol with acetone in the presence of acid catalyst.

A number of by-products are formed in conjunction with the main reaction. The earlier processes eliminated these impurities by batchwise crystallization, while the new process, the Hooker process, employs a continuous distillation and extractive crystallization under pressure to purify the product.

Phenol and acetone at a molar ratio of approximately 3 to 1 are mixed, saturated with hydrogen chloride gas, and sent to the reaction vessel. Reaction conditions are about 40°C, close to atmospheric pressure, with a mercaptan used as a catalyst. The crude product is stripped of HCl and water of reaction. The overhead is decanted into an organic phase (consisting mainly of phenol which is recycled) and an aqueous phase. The latter goes on to an HCl recovery unit, and water is sent to disposal.

Bottoms from the stripper are sent to a series of purification distillation chambers, where excess phenol, isomers, and heavy ends are removed from the system for either recycle or disposal. Distillate from the last chamber is sent to the extraction operation, which produces a slurry of pure crystals. The filtrate from the centrifuge



is partially recycled to the crystallizer, and the remainder is concentrated in an evaporator to produce liquid bisphenol-A.

2. Input Materials

Phenol - 862.5 kg/Mg (1725 lb/ton) product (excluding recycled excess)

Acetone - 265.9 kg/Mg (531.7 lb/ton) product

3. Operating Parameters

Temperature: 40°C (104°F)

Pressure: Near atmospheric

Flow Rates: Not given

Catalysts: HCl, and mercaptan

4. Utilities

Water (process) - 250 kg/Mg (500 lb/ton) product

(gross cooling) - 197 Mg/Mg (394,000 lb/ton) product

5. Waste Streams - Aqueous waste streams are produced by the hydrogen chloride recovery unit, the crystallizer, and the final evaporator.

Total water flow - 458.8 dm<sup>3</sup>/Mg (133.6 gal/ton) product

COD - 17.1 kg/Mg (34.2 lb/ton) product

TOC - 5.2 kg/Mg (10.3 lb/ton) product

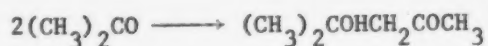
Phenol - 7.1 kg/Mg (14.2 lb/ton) pressure

6. EPA Source Classification Code - None

7. References

Anon., "Development Document for Effluent Limitations Guidelines and Standards of Performance: Organic Chemical Industry," Contract No. 68-01-1509, prepared for Environmental Protection Agency, June 1973.

Sittig, M., "Pollution Control in the Organic Chemical Industry," Pollution Technology Review No. 9, Noyes Data Corporation, 1974, p. 85-87.

Diacetone Alcohol (condensation of acetone)

1. Function - Diacetone alcohol is prepared by the aldol condensation of acetone flowing over a solid alkali or alkaline earth catalyst in a fixed-bed catalytic reactor. The reaction is normally carried out near room temperature or below.

To secure good yields it is necessary to remove the diacetone alcohol as fast as it is formed.

Once the product solution is out of contact with the catalyst, the dimer has little tendency to revert to acetone and accumulates. Acetone, being more volatile, is continually removed by distillation and recycled. Acetone-free diacetone alcohol is obtained by fractional distillation under vacuum.

2. Input Materials

Acetone

3. Operating Parameters

Temperature - 10-23°C (50-73°F)

Pressure - Not given

Catalyst - Ba(OH)<sub>2</sub> or similar compounds

4. Utilities - Not given

5. Waste Streams - Some acetone and diacetone alcohol may be present in air emissions from various processing equipment.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Chemicals - Part 7,"

"Chemical Engineering, June 24, 1974, p. 153.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 309.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 165-166.

Ibid., Vol. 12 (1967).

Hexylene Glycol

1. Function - Hexylene glycol is commercially prepared by the hydrogenation of diacetone alcohol.

In normal plant procedure, acetone is the raw material, undergoing preliminary condensation to diacetone alcohol.

2. Input Materials

Diacetone alcohol (from acetone - 1.2 kg/kg hexylene glycol)

Hydrogen

3. Operating Parameters - Not given

4. Utilities

Not given

5. Waste Streams - Air vent streams from the reactor contain hydrogen and acetone. Off-gas streams from the purification process contain acetone and some diacetone alcohol.

6. EPA Source Classification Code

None

7. References

Hancock, E. G., Propylene and Its Industrial Derivatives, John Wiley and Sons, Inc., New York, 1973, p. 258.

Mesityl Oxide (dehydration of diacetone alcohol)

1. Function - Mesityl oxide is commercially produced by dehydrating diacetone alcohol at 100°C in the presence of sulfuric acid.
2. Input Materials - Diacetone alcohol and  $\text{H}_2\text{SO}_4$
3. Operating Parameters  
Temperature - 100°C (212°F)  
Pressure - Not given
4. Utilities - Not given
5. Waste Streams - Wastewater from the dehydration column may contain some acetone and diacetone alcohol.
6. EPA Source Classification Code - None
7. References  
Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967) p. 136.  
Waddams, A. L., Chemicals From Petroleum, 3rd Edition, John Murray Publishers, Ltd., London, Eng., 1973, p. 126.

Methyl Isobutyl Ketone (hydrogenation of mesityl oxide)

1. Function - Methyl isobutyl ketone is made commercially by the selective catalytic hydrogenation of the olefinic linkage in mesityl oxide. The reaction may be run in the vapor phase at 150-170°C and 100 kPa (1 atm) or in the liquid phase at 60-130°C and 1-25 atm. Copper or Raney nickel catalysts are used.

In normal plant procedure, acetone is the raw material undergoing conversion to diacetone alcohol, mesityl oxide, and finally methyl isobutyl ketone (see Process Nos. 257 and 259). Methyl isobutyl carbinol is a by-product of this reaction.

2. Input Materials

Mesityl oxide

Hydrogen

3. Operating Parameters

Vapor Phase - Temperature: 150-170°C (302-338°F)

Pressure: 100 kPa (1 atm)

4. Utilities - Not given

5. Waste Streams - Air emissions from the purification section may contain mesityl oxide, methyl isobutyl ketone, methyl isobutyl carbinol, and other by-products.

6. EPA Source Classification Code - None

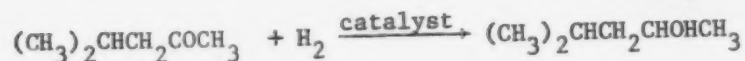
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7," "Chemical Engineering," June 24, 1974, p. 153.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 309.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 134.



Methyl Isobutyl Carbinol (from methyl isobutyl ketone)

1. Function - Methyl isobutyl carbinol is produced on a commercial scale by the hydrogenation of methyl isobutyl ketone.

It is also isolated and collected as a by-product of methyl isobutyl ketone synthesis (see Process No. 260).

2. Input Materials

Methyl isobutyl ketone

Hydrogen

3. Operating Parameters

Temperature: 150-190°C (302-374°F)

Pressure: 345-689 kPa (3.4-6.8 atm)

4. Utilities - Not given

5. Waste Streams - Some air emissions may be present. The probable pollutants are methyl isobutyl ketones, methyl isobutyl carbinol, and reaction by-products.

6. EPA Source Classification Code - None

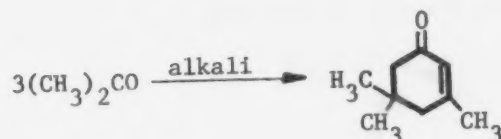
7. References

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Co., New York, N.Y., 1956, p. 202, 228.

Hahn, A. V., The Petrochemical Industry, McGraw-Hill Book Co., New York, 1970, p. 367.

7. References (continued)

Hancock, E. G., Propylene, John Wiley and Sons, New York, 1973,  
p. 258-259.

Isophorone (vapor-phase condensation of acetone)1. Function

Isophorone is prepared by the vapor phase condensation of three molecules of acetone in the presence of an alkaline catalyst. A liquid phase condensation may also be employed. In the vapor phase process, acetone is passed over calcium oxide, hydroxide, or carbide at 350°C and atmospheric pressure to give isophorone, water and by products such as: diacetone alcohol and mesityl oxide. The isophorone is purified by vacuum distillation.

2. Input Materials - Acetone3. Operating Parameters

## Vapor phase

Temperature: 350°C (662°F)

Pressure: 100 kPa (1 atm)

Catalyst: CaO, Ca(OH)<sub>2</sub> or CaC<sub>2</sub>

## Liquid phase

Temperature: 140-170°C (284-338°F)

Pressure: not given

4. Utilities - not given

5. Waste Streams - Air emissions from purification operations may contain unconverted acetone, mesityl oxide, diacetone alcohol, other reaction by-products and isophorone.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963) p. 166.

Sherwood, P. W., "Petroleum Refiner," 33 (12), 144 (1954).

Ketene (pyrolysis of acetone)

1. Function - On a commercial scale, ketene is prepared by the straight pyrolysis of acetone. In the noncatalytic process, acetone is heated to 600°C where it cracks to ketene and methane. Ketene is a highly reactive material, unstable in storage. It is manufactured only for captive use in further synthetic operations. Ketene dimerizes spontaneously and is a commercial by-product of ketene synthesis.
2. Input Material - Acetone
3. Operating Parameters  
Temperature - 650-670°C (1202-1238°F)  
Pressure - not given  
Contact time - 0.25-5 sec.
4. Utilities - Not given
5. Waste Streams - The off-gas from the reactor should contain large quantities of methane, and smaller amounts of acetone and possibly acetic acid (reaction of ketene and water).
6. EPA Source Classification Code - None
7. References  
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 129.  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 12 (1967), p. 91.

7. References (continued)

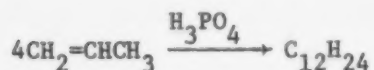
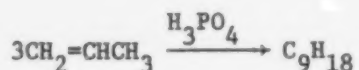
Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 18.

Diketene (dimerization of ketene)

1. Function - Diketene is a commercial by-product of ketene synthesis from acetic acid (see Process No. 105) or acetone (see Process No. 263A). The dimerization occurs spontaneously.

For description of the other items see Process No. 263A.



Nonene and Dodecene (oligomerization of propylene)

1. Function - Nonene and dodecene are coproduced when a C<sub>3</sub> refinery stream (40-60% propylene/propane) is oligomerized in the presence of a phosphoric acid catalyst at 200°C and 3.45-6.89 MPa.

In some cases, the oligomerization is done with the intention of producing gasoline, from which cuts of nonene and dodecene can be fractionated. In other cases, the tetramer and/or trimer are the primary products desired and the oligomerization is carried out in such a way as to maximize production of both or either of these. For instance, if the demand for dodecene exceeds the quantity contained in a once-through oligomerization product, some or all of the dimer and trimer are recycled to increase or maximize production of the tetramer.

The trimer and tetramer cuts that are fractionated from the oligomerization product are not pure trimer and tetramer, but are mixtures of olefins that consist principally of polypropylene having average molecular weights corresponding to those of nonene and dodecene.

2. Input Materials

Propylene\* (component of C<sub>3</sub> Refinery Gas)

\* The figures presented represent maximized production of nonene and dodecene.

2. Input Materials (continued)

For nonene - 1.21 kg/kg

For dodecene - 1.27 kg/kg

3. Operating Parameters

Temperature: 200°C (392°F)

Pressure: 3.45-6.89 MPa (34-68 atm.)

Catalyst:  $\text{H}_3\text{PO}_4$

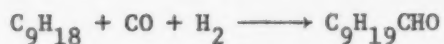
4. Utilities - Not given

5. Waste Streams - Since all of the co-products of nonene and dodecene manufacture are utilized, there are no process wastes to be dealt with, except spent phosphoric acid catalyst. However, propylene, nonene, dodecene, and other olefins may be leaked to the atmosphere by various processing equipment.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 335.

Isodecyl Alcohol (oxo process)

1. Function - Isodecyl alcohol, actually a mixture of trimethyl heptanols, is prepared from nonene by the oxo process. In this process, a mixed stream of nonylenes is combined with synthesis gas at 160°C and 1.38 MPa (137 atm) in the presence of cobalt naphthenate catalyst to produce a mixture of  $\text{C}_{10}$  aldehydes.

The intermediate aldehydes are then hydrogenated to isodecyl alcohol at 150°C and 10.0 MPa (100 atm) over a nickel or copper chromite catalyst:



Purification is carried out in the manner described in Process Nos. 278 and 282. Yields in the neighborhood of 64% are obtained.

2. Input Materials

Nonene - 1.25 kg/kg product

Synthesis gas

Hydrogen

3. Operating Parameters

Aldehyde Production

Temperature: 160°C (320°F)

Pressure: 13.8 MPa (137 atm)

Catalyst: Cobalt naphthenate

3. Operating Parameters (continued)

Hydrogenation

Temperature: 150°C (302°F)

Pressure: 10.0 MPa (100 atm)

Catalyst: Ni or Cu chromite

4. Utilities - Not given

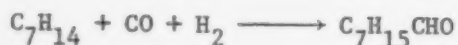
5. Waste Streams - Generally, the same types of pollution would be expected as in Process Nos. 187 and 188.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2" "Chemical Engineering," March 18, 1974, p. 92.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 14 (1967), p. 373-89.

Isooctyl Alcohol (from heptene)

1. Function - Isooctyl alcohol, actually a mixture of isomeric  $\text{C}_8$  alcohols, is manufactured by the oxo process. Heptene and synthesis gas are reacted at  $150^\circ\text{C}$  and 20.7 MPa (3000 psi) in the presence of a cobalt carbonyl catalyst, to yield a mixture of intermediate octaldehydes.

After separation, the octaldehydes are hydrogenated to isooctyl alcohol at  $150^\circ\text{C}$  and 10.0 MPa (100 atm) over a nickel chromate catalyst.

The intermediate aldehyde and the crude alcohol product are purified by the methods described in Process Nos. 278 and 282. This process gives a 57% yield based on heptene.

2. Input Materials

Heptene - 1.33 kg/kg product

Synthesis gas

Hydrogen

3. Operating Parameters

Temperature:  $150^\circ\text{C}$  ( $302^\circ\text{F}$ )

Pressure: octaldehyde production - 20.7 MPa

hydrogenation - 10.0 MPa

Catalyst: octaldehyde production - cobalt carbonyl

hydrogenation - nickel chromate

4. Utilities - Not given

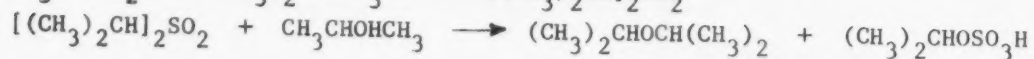
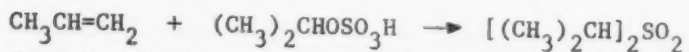
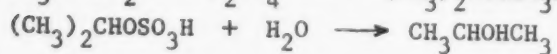
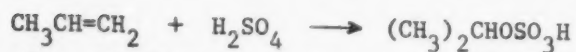
5. Waste Streams - Generally, the same types of pollution would be expected as in Process Nos. 187 and 188.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 14 (1967). p. 373-89.

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 6," "Chemical Engineering," May 27, 1974, p. 106.

2-Propanol (Isopropyl Alcohol; Indirect Hydration Process)

1. Function - The basic reactions of the indirect hydration process for the production of isopropyl alcohol are described in the above formulae.

Crude propylene is scrubbed to remove mercaptans and hydrogen sulfide, distilled to remove higher hydrocarbons and hydrogenated to remove the acetylenics.

The liquefied propylene feed stock is combined with recycled propylene and passed into a sulfuric acid absorption column. Most of the propylene is absorbed. The spent gas containing propylene and propane is scrubbed with caustic and sent to liquefied petroleum gas (LPG).

The extract is sent to the hydrolyzer-stripper where it is diluted with water to obtain the sulfate esters. The ester solution is then stripped with steam to remove the 2-propanol and diisopropyl ether. The alcohol and ether vapors are scrubbed with caustic solution to remove acidic compounds and entrained acid.

The alcohol and ether are separated by distillation, the ether being taken overhead as a water-ether azeotrope. The alcohol-water mixture is distilled and the distillate sent to a dehydrating column where the remaining water is removed azeotropically. The



ternary azeotrope is condensed and sent to a decanter where two layers are formed. The upper layer consists of alcohol and azeotropic components, the lower layer is water.

2. Input Materials

Refinery propylene stream (>50% propylene)

Sulfuric acid (70-80 wt %)

Caustic soda

Azeotropic agent (benzene, isopropyl ether or ethyl ether)

3. Operating Parameters

Absorber (reactor) temperature: 60-90°C (140-190°F)

Absorber (reactor) pressure: 791 kPa-28.6 MPa (7.8-28.3 atm)

4. Utilities - Not given

5. Waste Streams

Air: possible compressor seal leaks, recycle gas line leaks, spent gas vent on reactor would result in propylene emissions.

Water: Waste water from dehydration column and crude storage may contain small amounts of isopropyl ether, hydrocarbons, and propanoic acid. Spent caustic soda solution contains caustic soda, sodium sulfate, and 2-propanol. Waste water from the decanter may contain isopropanol and azeotropic components.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 16 (1967), p. 568-570.

Kent, J. A., Riegel's Handbook of Industrial Chemistry, Ed., 7th Edition, Van Nostrand Reinhold Company, New York, N. Y., 1974, p. 794.

Isopropyl Chloride (from isopropyl alcohol)



1. Function - Isopropyl chloride is readily formed by the reaction of isopropyl alcohol and hydrochloric acid.
2. Input Materials  
Isopropyl alcohol  
Hydrochloric acid
3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Air and water effluents from the separator may contain isopropanol, isopropyl chloride, and hydrogen chloride.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 16 (1968), p. 567.

Acetone (oxidation of isopropanol)

1. Function - A significant amount of acetone is produced by the catalytic oxidation of isopropyl alcohol. In this process, isopropanol is mixed with air and fed to a reactor maintained at 500°C and 345 kPa (50 psi). Copper or silver catalysts are used.

Reactor products are treated similarly to those from the straight dehydrogenation process.

If run in the liquid phase, this process yields hydrogen peroxide as a by-product.



2. Input Materials

Isopropanol - 1.15 kg/kg product

Air

3. Operating Parameters

Temperature: 500°C (932°F)

Pressure: 345 kPa (3.4 atm)

Catalyst: copper or silver

4. Utilities - Not given

5. Waste Streams

Isopropanol stripping still and intermediate flush column (water).

5. Waste Streams (continued)

Water flow -  $1.46 \text{ m}^3/\text{Mg}$  product (350 gal/ton)

COD - 1.1 kg/Mg product (2.2 lb/ton)

BOD - 3.25 kg/Mg product (6.5 lb/ton)

TOC - 0.35 kg/Mg product (0.7 lb/ton)

The waste water contains acetone, isopropanol and traces of heavier organics.

Vent on absorber (air) - acetone and isopropanol vapors.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 130.

Hedley, W. H. et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 161.

Acetone (catalytic dehydrogenation of isopropanol)

1. Function - As of November 1974, 42% of the U. S. capacity for acetone production was based on the dehydrogenation or oxidation (see Process No. 269) of isopropyl alcohol. In the dehydrogenation process, isopropanol is fed to a packed tubular reactor. The reaction takes place at 380°C in the presence of brass or zinc oxide catalyst, with a yield of 95%.

The hot reactor effluent contains acetone, unreacted isopropanol, hydrogen, and minor amounts of by-products, such as propylene and diisopropyl ether. The mixture is cooled and the noncondensable gases are scrubbed with water. Because the resultant gas stream is mainly hydrogen, a part of it can be recycled to control catalyst fouling. The liquids are fractionally distilled taking reconcentrated acetone overhead and a mixture of isopropanol and water as bottoms. In a second fractionating column, the aqueous isopropyl alcohol is concentrated for recycle to the reactor. The water removed may be rejected or reused in the gas scrubber.

2. Input Material - Isopropanol - 1.25 kg/kg acetone
3. Operating Parameters

Temperature - 380°C (716°F)

Pressure - Not given

Catalyst - brass or ZnO

4. Utilities - Basis: 2.16 kg/sec (150 M lb/yr) capacity

Cooling water -  $379 \text{ dm}^3/\text{sec}$  (6000 gpm)

Makeup water -  $6.3 \text{ dm}^3/\text{sec}$  (100 gpm)

Power - 1080 MJ (300 kW)

Steam - 10.1 kg/sec (80,000 lb/hr)

Natural gas - 8.8 MW (30 M Btu/hr)

5. Waste Streams

Isopropanol stripping still and intermediate flash column (water).

Water flow -  $1.46 \text{ m}^3/\text{Mg}$  product (350 gal/ton)

COD - 1.1 kg/Mg product (2.2 lb/ton)

BOD - 3.25 kg/Mg product (6.5 lb/ton)

TOC - 0.35 kg/Mg product (0.7 lb/ton)

The wastewater contains acetone, isopropanol, and traces of heavier organics.

Vent on absorber (air)

Acetone and isopropanol vapors

6. EPA Source Classification Code - None

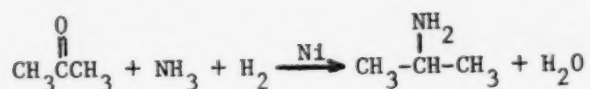
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1,"

"Chemical Engineering," January 21, 1974, p. 129.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 160.

Isopropyl Amine (from isopropyl alcohol or acetone)

1. Function - Isopropyl amine is made principally by two vapor phase catalytic processes. The first involves the alkylation of ammonia by isopropyl alcohol. This reaction is run at 350°C under a pressure of 100-200 atmospheres using an aluminum phosphate catalyst. An excess (3 to 5x) of ammonia is used in order to promote primary amine formation. Secondary and tertiary amines are by-products and must be separated. The amines appear to be in equilibrium and the secondary and tertiary amines are therefore recycled.

Acetone, ammonia and hydrogen are combined at 140°C and 740 psi over Raney nickel to give a 97% yield of isopropylamine. Secondary and tertiary amines are also present as by-products of this reaction.

2. Input Materials

Isopropyl Alcohol

Ammonia

Acetone

Hydrogen

3. Operating Parameters

Ammonylsis

Temperature - 350°C (662°F)

Pressure - 10.1-20.3 MPa (100-200 atm)



3. Operating Parameters (Continued)

Catalyst - Aluminum phosphate

Reductive Ammination

Temperature - 130-180°C (266-356°F)

Pressure - 0.507-10.1 MPa (5-100 atm)

Catalyst - Raney nickel

4. Utilities - not given

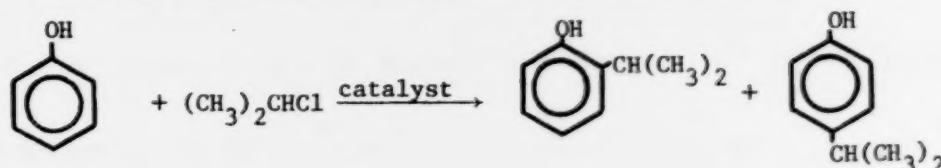
5. Waste Streams - Waste water streams from strippers may contain ammonia, isopropyl alcohol, acetone, isopropyl amines and more highly substituted amines. Air effluents may contain ammonia, acetone, isopropyl amine and isopropyl alcohol.

6. EPA Source Classification Code - None

7. References

E. G. Hancock, Propylene and Its Industrial Derivatives, John Wiley and Sons, New York, N.Y., 1973, p. 223-234.

A. L. Waddams, Chemicals from Petroleum, 3rd Edition, John Murray Publishers, Ltd., London, 1973, p. 128.

Isopropyl Phenols (from isopropyl chloride and phenol)

1. Function - Isopropyl phenols are produced by Friedel-Crafts reaction of phenol and isopropyl chloride in the presence of  $\text{AlCl}_3$ ,  $\text{BF}_3$ , or  $\text{H}_2\text{SO}_4$  catalyst.

Ortho- and para-isopropylphenol are the primary products, although some polysubstitution does occur.

2. Input Materials

Phenol

Isopropyl chloride

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst:  $\text{AlCl}_3$ ,  $\text{BF}_3$ , or  $\text{H}_2\text{SO}_4$

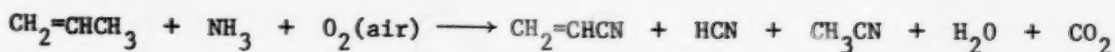
4. Utilities - Not given

5. Waste Streams - Waste water from the HCl scrubber should contain sodium chloride and caustic, phenol, isopropyl chloride, spent catalyst, and isopropylphenol. The air effluent may contain HCl, isopropyl chloride, and reaction by-products. Tars from the still bottoms are probably incinerated.

6. EPA Source Classification Code - None

7. References

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 129, 269.

Acrylonitrile/Acetonitrile (ammoxidation of propylene)

1. Function - The entire production of acrylonitrile in the United States is obtained by the ammoxidation of propylene. In this vapor-phase process, refinery propylene (90+%), fertilizer grade ammonia (99.5+%), and air are combined in a fluidized bed reactor at 450°C and 200 kPa (2 atm). The reaction is catalyzed by a Sohio developed product, Catalyst 41 (50-60% bismuth phosphonohydrate on  $\text{Al}_2\text{O}_3$ ), which increases the yield of acrylonitrile and decreases the production of acetonitrile and hydrogen cyanide. Approximately 15 kg of acetonitrile and 75 kg of hydrogen cyanide are produced per Mg of acrylonitrile.

The reactor effluent is scrubbed in a countercurrent absorber, and excess ammonia is neutralized with sulfuric acid. The organic materials are recovered from the absorber water by distillation. Hydrogen cyanide, water, light ends, and high boiling impurities are then removed from the crude acrylonitrile by fractionation at atmospheric pressure. Acetonitrile and hydrogen cyanide are collected as saleable by-products.

2. Input Materials - Basis - 1 metric ton acrylonitrile

|                               |                                                                   |
|-------------------------------|-------------------------------------------------------------------|
| Propylene - 1.0 kg/kg product | 1175 kg (2,590 lbs/ton)                                           |
| Ammonia - 0.5 kg/kg product   | 475 kg (1,047 lbs/ton)                                            |
| Air - 10.0 kg/kg product      | 6090 m <sup>3</sup> (2.15 x 10 <sup>5</sup> ft <sup>3</sup> /ton) |
| Sulfuric acid                 | -                                                                 |
| Catalyst                      | small                                                             |

3. Operating Parameters

Temperature: 450°C (842°F)

Pressure: 200 kPa (2 atm)

Reaction Time: 10-20 sec.

4. Utilities - Basis: 2.87 kg/sec capacity (200 M lb/yr)

Cooling water - 1.89 m<sup>3</sup>/sec (30,000 gpm)

Refrigeration - 907 Mg (1000 tons)

Process water - 315 cm<sup>3</sup>/sec (5 gpm)

Electricity - 3.6 GJ (1000 kW)

Steam - 25.2 kg/sec (200,000 lb/hr)

Inert gas, high pressure - 23.6 dm<sup>3</sup>/sec (3000 scfh)

5. Waste Streams - Reaction section - absorber off-gases to flare (air)

Acrylonitrile - 5.0 kg/Mg product

Carbon monoxide - 200 kg/Mg product

Propane - 50.0 kg/Mg product

Propylene - 100 kg/Mg product

Acetonitrile - trace

Ammonia - trace

Purification section - off gas from drying column to flare (air)

Hydrogen cyanide - 1 kg/Mg product

Reaction section - neutralizer (water)

Wastewater contains ammonium sulfate

Purification section - stripper (water)

Wastewater may contain acetonitrile.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -

Part 1, "Chemical Engineering," January 21, 1974, p. 131.

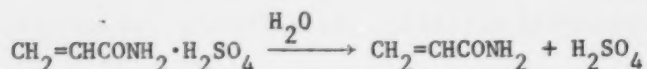
"1973 Petrochemical Handbook," "Hydrocarbon Processing," November, 1975, p. 99.

Hedley, W. H., et. al., Potential Pollutants from Petrochemical Processes,

Technomic Publishing Co., 1975.

7. References (continued)

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, p. 46,47.

Acrylamide (hydration of acrylonitrile)

1. Function - The hydration of acrylonitrile to acrylamide sulfate followed by dilution accounts for most acrylamide production at the present time. This reaction is carried out at 155-175° by adding acrylonitrile to sulfuric acid at the concentration corresponding to its monohydrate. Dilution with water converts the acrylamide sulfate intermediate to acrylamide and sulfuric acid.

To prevent hydrolysis to acrylic acid, free acid must be removed from the crude product solution. This is most commonly achieved by neutralization with ammonia or sodium hydroxide to form water-insoluble sulfate salts. The salts are then removed by filtration and the filtrate is concentrated and/or cooled to recover crystals of acrylamide. The mother liquor is frequently purged and recycled to serve as the medium for further neutralization.

The sulfuric acid may be directly separated from the crude product mixture without neutralization. This is accomplished by means of an ion exchange column which separates the product mixture into successive fractions of sulfuric acid, acrylamide-acrylic acid and acrylamide.

In July 1974, one U.S. company began producing acrylamide by the direct hydrolysis of acrylonitrile over special catalysts. A number of catalysts have been developed that allow the hydrolysis

of acrylonitrile in aqueous solution to yield the acrylamide directly, obviating the need for the separation procedure necessary in the sulfuric acid hydrolysis. These catalysts consist for the most part of activated metallic oxides and are regenerable. These reactions are run at 100°C and it is necessary to include a water soluble inhibitor to prevent polymerization of the acrylamide. In one case where the catalyst was 40% Cu salt - 25.5% Cr the inhibitor used was N-nitroso-N-phenyl hydroxyamine ammonium salt. For a 7% aqueous solution of acrylonitrile 25 ppm was sufficient to inhibit the polymerization.

2. Input Materials

Acrylonitrile - 0.95 kg/kg acrylamide

Concentrated sulfuric acid

Water

Ammonia or sodium hydroxide

3. Operating Parameters

Temperature - hydrolysis

reaction - 155-175°C (311-347°F)

neutralization 50°C (122°F)

catalytic - 90-105°C (194-221°F)

Pressure - not given

4. Utilities - not given

5. Waste Streams - The principal pollutants from this process should be the impurities removed from the mother liquor following acrylamide separation. Acrylic acid, acrylonitrile, ammonia or caustic soda, inorganic sulfates, and traces of acrylamide may be present in this waste stream.



The principal pollutants from the catalytic process are the impurities remaining in the mother liquor following the recrystallization of acrylamide. Unreacted acrylonitrile, inhibitor and some acrylamide are present. Catalyst is recovered by filtration and except for fines does not present a problem.

6. EPA Source Classification Code - None

7. References

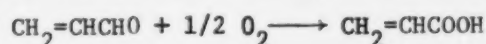
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 1., (1963), p. 278-280.

U.S. Patent 3,699,194 (1974).

U.S. Patent, 3,689,558 (Dow Chemical 1974).

Succinonitrile (from acrylonitrile)

1. Function - Succinonitrile, also known as ethylene cyanide, is manufactured by reacting acrylonitrile with HCN in the presence of a catalyst (~5 wgt % acrylonitrile) and an inert solvent (tert-butyl alcohol). The acrylonitrile is added gradually to prevent polymerization.
2. Input Materials  
Acrylonitrile  
Hydrogen Cyanide  
Catalyst: (Triton B) (benzyltrimethylammonium hydroxide)  
Solvent: tert-Butyl Alcohol
3. Operating Parameters  
Temperature: 55-60° C (131-140°F)  
Pressure: 101 kPa (1 atm)  
Reaction time: 5 hrs.
4. Utilities - Not given
5. Waste Streams - Wastewater streams from the purification section may contain alcohol and smaller quantities of acrylonitrile, hydrogen cyanide, catalyst, and polymers of acrylonitrile.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 641.

Acrylic Acid (oxidation of propylene)

1. Function - The fastest-growing route to acrylic acid involves a one-or two-stage oxidation of propylene in the presence of a molybdenum oxide catalyst.

In the two-step process, propylene, steam, and preheated air are fed to the first reactor filled with oxidation catalyst. The temperature is maintained at 330 - 370°C by circulating heat transfer medium. The crude acrolein product is fed directly to the second reactor where it is converted to acrylic acid at 260 - 300°C. The reaction may be run in a single reactor by raising the temperature to 350 - 400°C and using a pressure of 98-196 kPa.

Regardless of the conversion technique, the reactor effluent is introduced to an absorber where acrylic acid is scrubbed as an aqueous solution. Acrylic acid in the solution is then extracted with a solvent. After solvent separation and light ends removal, high purity acrylic acid is obtained at the final rectifier. Some acetic acid by-product may be recovered.

2. Input Materials

Propylene - 0.83 kg/kg acrylic acid

Air

Steam - see utilities

3. Operating Parameters

Temperature: one stage - 350 - 400°C (662-752°F)

two stage - first reactor - 330 - 370°C (626-698°F)

second reactor - 260 - 300°C (500-572°F)

Pressure: 100 - 200 kPa (1-2 atm.)

Catalyst:  $\text{MoO}_3$

4. Utilities<sup>\*</sup> - Basis: 0.31 kg/sec capacity (21.6  $\bar{\text{M}}$  lb/yr)

Steam - 3.11 kg/sec (24,700 lb/hr)

Power - 0.97 GJ (270 kW)

Cooling water - 379.1  $\text{dm}^3/\text{sec}$  (6,009 gpm)

Makeup water - 20.3  $\text{dm}^3/\text{sec}$  (322 gpm)

Electricity - 3.9695 (1,100 kWh) metric ton

5. Waste Streams<sup>\*</sup> - Overhead of solvent recovery column (air)

Acetone - 0.35 kg/Mg product

Acrolein - 1.85 kg/Mg product

Ethyl acetate - 1.85 kg/Mg product

Off-gas from the  $\text{C}_3$  recovery system (air)

Ethyl acetate - 36.8 kg/Mg product

Propylene - 6.25 kg/Mg product

Carbon monoxide - 502 kg/Mg product

Heavy ends from acrylic acid finishing system (water)

Acrylic acid - 4 kg/Mg product

Polymers - 20.6 kg/Mg product

Hydroquinone - 10.65 kg/Mg product

Bottom from ethyl acetate recovery system (water)

Acetic acid - 35.7 kg/Mg product

Acrylic acid - 5.9 kg/Mg product

Ethyl acetate - 27.25 kg/Mg product

<sup>\*</sup> Data is based on the one-step oxidation.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 1," Chemical Engineering, January 21, 1974, p. 130,313.

"1973 Petrochemical Handbook," Hydrocarbon Processing,  
November, 1973, p. 96.

Hedley, W. H., et al., Potential Pollutants from Petrochemical  
Processes, Technomic Publishing Co., 1975.

n-Butyl Acrylate (from acrylic acid)

1. Function - One competitive process for making n-butyl acrylate involves the direct esterification of acrylic acid with n-butanol.

Sulfuric acid is normally used as the catalyst and benzene is used as a water entrainer to assist in driving the reaction to completion.

2. Input Materials

Acrylic acid

n-Butanol

Benzene

3. Operating Parameters

Temperature: not given

Pressure: not given

Catalyst:  $\text{H}_2\text{SO}_4$

4. Utilities - not given

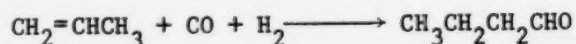
5. Waste Streams - Waste water streams, if present, may contain acrylic acid, sulfuric acid, n-butanol, n-butyl acrylate, and benzene.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 126, 127.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 299.

n-Butyraldehyde (oxo process)

1. Function - In the oxo process, propylene is reacted with synthesis gas in the liquid phase at 140-170°C and 20-30 MPa (200-300 atm). An aromatic liquid such as toluene is used as the solvent, and cobalt carbonyl compounds catalyze the reaction. n-Butyraldehyde, isobutyraldehyde, and some butanol are produced. In modern plants the ratio of n-butyraldehyde to isobutyraldehyde is 4:1. The cobalt catalyst is separated from the crude oxo product and recycled to the reactor without any loss.

The two aldehydes may be hydrogenated and the corresponding alcohols separated by distillation, or the aldehydes may be separated and hydrogenated individually.

The remainder of the product mixture, containing butanols, esters, and heavy ends, is separated in a third column to yield small quantities of butanol and a residue which is used as fuel.

2. Input Materials

Propylene - 0.75 kg/kg n-butyraldehyde

Synthesis gas (CO and H<sub>2</sub>)

Toluene (or other solvents)

3. Operating Parameters

Temperature - 140-170°C (284-338°F)

Pressure - 20-30 MPa (197-296 atm)

Catalyst - Cobalt carbonyl compound



4. Utilities

Not given

5. Waste Streams

Catalyst recovery section (air, water)

Air vents discharge carbon monoxide, propylene, and propane. Some catalyst recovery systems have a wastewater stream.

Purification section (air)

Various light end by-products may be flared to the atmosphere.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2", "Chemical Engineering," February 18, 1974, p. 126.

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973, p. 107.

Hedley, W. H., et. al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Isobutanol (hydrogenation of isobutyraldehyde)

1. Function - Isobutanol is produced by the catalytic hydrogenation of isobutyraldehyde in a process similar to that used to make n-butanol from n-butyraldehyde. The reaction is carried out at 10.0 MPa pressure, and water is added to suppress ether formation.

Some n-butanol is also produced by this reaction due to aldehyde isomerization. The isobutanol, n-butanol, and other by-products are separated by the methods described in Process No. 282.

2. Input Materials

Isobutyraldehyde - 1.10 kg/kg product

Hydrogen

Water

3. Operating Parameters

Temperature: 130-250°C (266-482°F)

Pressure: 10.0 MPa (100 atm)

Catalyst: nickel, copper chromite, or molybdenum sulfide

4. Utilities - Not given

5. Waste Streams - The same general types of pollution would be expected as in Process No.

6. EPA Source Classification Code - None

7. References

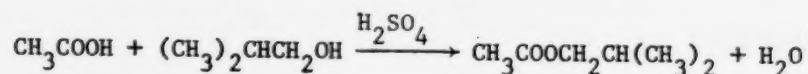
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 6," "Chemical Engineering," May 27, 1974, p. 104.

7. References (continued)

"1973 Petrochemical Handbook Issue," Hydrocarbon Processing,  
November 1973, p. 107.

Hedley, W. H., et al., Potential Pollutants from Petrochemical  
Processes, Technomic Publishing Co., 1975.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Murray,  
Ltd., London, England, 1973, p. 205.

Isobutyl Acetate (from isobutanol)

1. Function - Isobutyl acetate is formed by the esterification of acetic acid with isobutyl alcohol in the presence of sulfuric acid. The reaction is carried out at the reflux temperature of the ternary azeotrope of isobutyl alcohol, isobutyl acetate and water. The vapor mixture distilling at this temperature is sent to a separator where the water is separated into an aqueous and alcohol-ester fraction. The alcohol-ester layer is distilled giving an alcohol-ester azeotrope and pure ester.

2. Input Material - basis 1 kg isobutyl acetate

|                  |           |
|------------------|-----------|
| Isobutyl alcohol | .9 kg/kg  |
| Acetic acid      | .94 kg/kg |
| Sulfuric Acid    | 0.1%      |

3. Operating Parameters

|              |                       |
|--------------|-----------------------|
| Temperature: | 85-89°C (185 - 192°F) |
| Pressure:    | 100 kPa (1 atm.)      |
| Catalyst:    | Sulfuric acid         |

4. Utilities

Not available

5. Waste Streams - Isobutyl alcohol and isobutyl acetate will be emitted from the reflux condenser. Waste water streams from the separator contain acetic acid, dilute sulfuric acid, isobutyl alcohol and isobutyl acetate. Air vent streams from the purification system

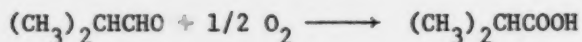
(distillation) will contain isobutyl alcohol and isobutyl acetate.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2," "Chemical Engineering," February 18, 1974, p. 126.

Faith, W. L., et al., Industrial Chemicals, 3rd Ed., John Wiley and Sons, Inc., New York, 1965, p. 176-78.

Isobutyric Acid (oxidation of isobutyraldehyde)

1. Function - Isobutyric acid is prepared in 95% yield by the air oxidation of isobutyraldehyde at 30-50°C.

The crude product is best purified by azeotropic distillation with water followed by fractional distillation.

In some cases, isobutyl alcohol may be the raw material for this oxidation.

2. Input Materials

Isobutyraldehyde - 0.86 kg/kg product

Air

Water

3. Operating Parameters

Temperature: 30-50°C

Pressure: not given

4. Utilities - Not given

5. Waste Streams - Waste water from distillation procedures may contain isobutyraldehyde, traces of isobutyric acid, and isobutanol, if used as the raw material in the synthesis. Waste gases from the purification section probably contain isobutyraldehyde and/or isobutanol.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 880.

n-Butanol

1. Function - About half of the commercial n-butanol is produced by the hydrogenation of n-butyraldehyde. In nearly all plant processes, the butyraldehyde feedstock is prepared by the oxo-reaction of propylene, so it contains isobutyraldehyde as well (see Process No. 278). In modern processes the hydrogenation reaction tends to isomerize the mixture to n-butanol.

A number of operating parameters have been reported for this reaction. In most cases, the butyraldehyde feed is converted with hydrogen over a fixed-bed catalyst such as nickel, copper chromite, or molybdenum sulfide at 130-250°C and 3-20 MPa (30-200 atm).

The crude n-butanol is purified by rectification in two columns. In the first column, the low boiling impurities, isobutanol and water, are separated as overhead. The higher-boiling impurities are removed in the second column by continuous discharge of the bottoms, product, and pure n-butanol is taken overhead.

2. Input Materials

n-Butyraldehyde (+ some isobutyraldehyde) - 1.09 kg/kg n-butanol

Hydrogen



3. Operating Parameters

Temperature - 130-250°C

Pressure - 3-20 MPa (30-200 atm)

Catalyst - nickel, copper chromite, or molybdenum sulfide

4. Utilities - Not given

5. Waste Streams

Hydrogenation reactor (air)

Tail gas vent discharges hydrogen and some organic vapors

Distillation column (organic liquid)

Heavy ends are usually burned.

This process involves no waste water and minimal air pollution.

6. EPA Source Classification Code - None

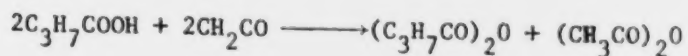
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 2,"  
"Chemical Engineering," February 18, 1974, p. 126.

"1973 Petrochemical Handbook Issue," "Hydrocarbon Processing,"  
November 1973, p. 153.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes,  
Technomic Publishing Co., 1975.

Waddams, A. L., Chemicals from Petroleum, 3rd Ed., John Murray, Ltd.,  
London, England, 1973, pp. 204-206.

n-Butyric Anhydride

1. Function - Butyric anhydride may be prepared by an exchange between butyric acid and acetic anhydride, or by the spontaneous reaction of butyric acid and ketene.

Since ketene may be synthesized from acetic acid (see Process No. 105), these reactions may be run in conjunction with each other. This system would require an initial input of either acetic acid or acetic anhydride.

2. Input Materials

Butyric acid

Acetic acid or acetic anhydride

3. Operating Parameters - Not given
4. Utilities - Not given
5. Waste Streams - Effluents from separation and purification operations may contain acetic acid, acetic anhydride, unreacted butyric acid, and butyric anhydride.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1964), p. 880.

n-Butyl Amines (from n-butyraldehyde)

1. Function - The most common route to n-butylamine involves the hydrogenation of n-butyraldehyde and alcoholic ammonia. The reaction is carried out at 90-125°C and elevated pressure in the presence of a nickel catalyst.

The yield of n-butylamine is about 80% with smaller amounts of di- and tri-n-butylamine by-products.

2. Input Materials

n-Butyraldehyde - 1.23 kg/kg n-butylamine

Ammonia

Hydrogen

Alcohol (solvent)

3. Operating Parameters

Temperature: 90-125°C

Pressure: -500-1000 kPa (5-10 atm)

Catalyst: nickel

4. Utilities - Not given

5. Waste Streams - The separator effluent may contain quantities of ammonia, n-butyraldehyde, alcoholic solvent, spent catalyst, various butylamines, and by-product n-butanol.

6. EPA Source Classification Code - None

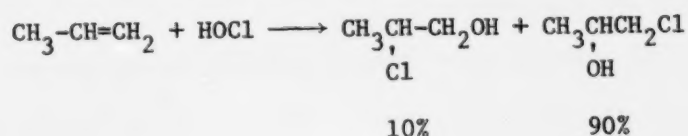
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 117, 124..

7. References (continued)

Ibid., Vol. 3 (1964), p. 868.

Koddo, N., Chem. Eng., 50(9), 149-68 (1952).

Propylene Chlorohydrin (from propylene)

1. Function - The bulk of propylene chlorohydrin produced in this country is made by the hydrochlorination of propylene. The method involves passing chlorine, propylene and water into a rubber-lined steel or acid-proof brick reactor at 35-50°C. The chlorine and water react to form hypochlorous acid and hydrochloric acid in a reversible reaction. The olefin is added to the hypochlorous acid at a rate which is maintained to produce a chlorohydrin of 3-5%. More concentrated solutions promote side reactions which yield bis(chloroisopropyl) ether and propylene dichloride.

The vent gases from the chlorohydrin tower are passed through a partial condenser to remove propylene dichloride and bis(chloroisopropyl) ether. The residual gas is scrubbed to remove HCl and in some cases recycled to the tower to recover any residual propylene. The propylene dichloride is purified and sold.

2. Input Materials

Propylene

Chlorine

Water

3. Operating Parameters

Temperature: 35-50°C (95-122°F)

Pressure: 110-130 kPa (1.14-1.27 atm)

4. Utilities - not available

5. Waste Streams - Waste water from scrubbing operations may contain sodium chloride and caustic soda. Reaction by-products, such as bis(chloroisopropyl) ether, may be present in air and waste water emissions from other purification sources. A portion of the recycled propylene may be vented to control the concentration of inert gases in the propylene feed. These emissions may contain ethylene, propylene, butane, hydrogen chloride and chlorine.

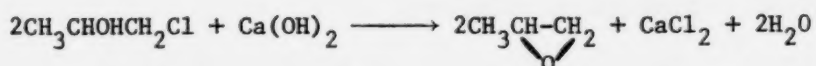
6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 111.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 16 (1968), p. 600-602.

Waddams, A. L., Chemicals from Petroleum, 3rd Ed., John Murray, Ltd., London, England, 1973, p. 137, 138.

Propylene Oxide (chlorohydrin process)

1. Function - As of July 1973, 70% of the U.S. capacity for propylene oxide production was based on the chlorohydrin process. In normal plant procedure, the propylene chlorohydrin feedstock is synthesized as described in Process No. 285. This dilute chlorohydrin solution is mixed with a 10% slurry of lime and pumped to a steam-heated flash hydrolyzer for conversion to propylene oxide. The reaction is carried out under ambient conditions.

The oxide is flashed out of the reaction zone as quickly as possible to prevent its further hydrolysis to propylene glycol. The lime slurry is used in excess and this excess may be recovered for recycle in thickeners which provide for the removal of the spent calcium chloride brine by decantation. This effluent consists of 5% aqueous  $\text{CaCl}_2$  containing traces of lime and propylene glycol.

The overhead from the hydrolyzer is largely propylene oxide and water. It is contaminated with propylene dichloride, chloroprenes from dehydrochlorination of propylene dichloride, and propionaldehyde from isomerization of propylene oxide. This crude product is purified by fractionation in multiple distillation columns.

2. Input Materials

Propylene chlorohydrin

(from propylene - 0.94 kg/kg propylene oxide)

10% Calcium hydroxide - 1.17 kg/kg product



3. Operating Parameters

Temperature: 25°C (77°F)

Pressure: ~atmospheric (100 kPa)

4. Utilities<sup>\*</sup> - Basis - 0.72 kg/sec capacity (50 M lb/yr)

Cooling water - 259 dm<sup>3</sup>/sec (4100 gpm)

Nitrogen - 23.6 dm<sup>3</sup>/sec (3000 cfh)

Power - 648 MJ (180 kW)

Refrigeration - 1.109 Gg (1222 tons)

Steam - 7.31 kg/sec (58,000 lb/hr)

5. Waste Streams<sup>\*</sup>

Purge gas from caustic absorber (air)

Ethane - 8.5 kg/Mg product

Butane - 8.5 kg/Mg product

Propylene - 8.5 kg/Mg product

Hydrogen chloride - 0.5 kg/Mg product

Chlorine - 0.5 g/Mg product

Off gas from tail gas absorber (air)

Propylene oxide - 4.1 kg/Mg product

Hydrogen chloride - 0.5 g/Mg product

Chloride - 0.5 g/Mg product

Water effluent

The major waste stream would probably contain calcium chloride and traces of lime and propylene glycol.

6. EPA Source Classification Code - None

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<sup>\*</sup> Includes Process No. 285

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 111.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 147-148.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 16 (1968), p. 600.

Mono- and Dipropylene Glycols

1. Function - Propylene glycol is produced by hydration of propylene oxide under pressure at temperatures up to 200°C. No catalysts are used.

Some dipropylene glycol, tripropylene glycol, and minor quantities of higher glycols are co-produced by the continued reaction of propylene oxide.

The proportion of higher glycols is controlled by the molar ratio of propylene oxide to water in the initial reaction mixture: the greater the dilution, the greater the production of propylene glycol and the higher the cost of recovering the pure products from solution. Usually about 15 moles of water are used per mole of propylene oxide in order to maximize propylene glycol production. This yields about 13% by weight dipropylene glycol and 1.5% tripropylene glycol.

Although most dipropylene glycol is recovered as a by-product of this process, some is produced by reacting propylene glycol with propylene oxide.

2. Input Materials

Propylene oxide

For propylene glycol - 0.77 kg/kg

2. Input Materials (continued)

For dipropylene glycol - 0.95 kg/kg

Water - 3.7 kg/kg product

3. Operating Parameters

Temperature: ~200°C

Pressure: not given

4. Utilities - Not given

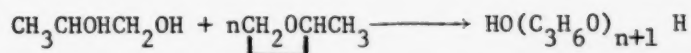
5. Waste Streams - The principal pollutant source in this process is waste water flow from the dehydrator, containing quantities of propylene oxide and propylene glycol.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 110-111.

Polypropylene Glycol

1. Function - Polypropylene glycol is produced by the base-catalyzed addition of propylene oxide to propylene glycol. The reaction takes place around 150°C.

Commercial polypropylene glycols have molecular weights ranging from 400 to 4000.

2. Input Materials

Propylene oxide

Propylene glycol

3. Operating Parameters

Temperature: 150°C

Pressure: Not given

Catalyst: KOH or other bases

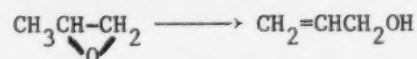
4. Utilities - Not given

5. Waste Streams - The same types of pollution would be expected as in Process No. 287. Spent catalyst may also be present.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering," July 22, 1974, p. 110.

Allyl Alcohol (isomerization of propylene oxide)

1. Function - Allyl alcohol is produced in 80-85% yield by the catalytic isomerization of propylene oxide. This rearrangement is carried out in the liquid phase in jacketed, stirred tank-type reactors at 200-300°C and 1-25 atm. Both lithium phosphate and lithium arsenate catalysts are used.
2. Input Material - Propylene oxide - 1.21 kg/kg allyl alcohol
3. Operating Parameters  
Temperature: 200-300°C (392-572°F)  
Pressure: 0.1-2.5 MPa (1-25 atm)  
Catalyst: lithium phosphate or arsenate
4. Utilities - Basis - 284 g/sec capacity (19.8 M lb/yr)  
Steam - 1.16 kg/sec (9200 lb/hr)  
Power - 302.4 MJ (84 kW)  
Fuel - 1159 MJ (1.1 M Btu/hr)  
Nitrogen - 157 scm<sup>3</sup>/sec (20 scfh)
5. Waste Streams  
Isomerization section - product column (water)  
Allyl alcohol - 13 kg/Mg product  
plus traces of n-propyl alcohol, tars, and xylene  
Catalyst tar removal section - auxiliary liquid column (water)  
Terphenyls - 12.5 kg/Mg product  
Lithium phosphate - 5 kg/Mg product  
Tars - 25.5 kg/Mg product

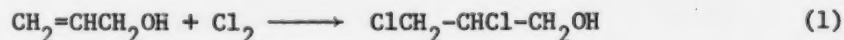
6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975, p. 151.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 10 (1966), p. 624.



Dichlorohydrin

1. Function - Dichlorohydrin is an intermediate in the production of glycerine. There are two principal processes used in the synthesis of dichlorohydrin. The starting materials in both processes are derived from propylene.

Allyl alcohol is chlorinated with chlorine gas to the dichlorohydrin. The product mixture contains 1,2-dichlorohydrin and 1,3-dichlorohydrin which need not be separated if this is the intermediate step in the synthesis of epichlorohydrin.

Allyl chloride is used as the starting material in a continuous chlorohydrination process. Chlorine, water and allyl chloride are fed to a stirred-reactor operating at 30-80°C and atmospheric pressure. The allyl chloride is kept low to inhibit side reactions which form 1,2,3-trichloropropane and chloroethane. The reaction yields a mixture of 1,2- and 1,3-dichlorohydrin in a 70-30 ratio.

The reactor effluent is lead to a separator where the aqueous and organic phases are separated. The aqueous phase is recycled to the reactor after additional chlorine is added. The organic phase is converted to epichlorohydrin.

2. Input Materials

Allyl alcohol

Chlorine

2. Input Materials (continued)

Allyl chloride - 0.98 kg/kg epichlorohydrin

Chlorine/water - 0.90 kg/kg epichlorohydrin

3. Operating Parameters

Temperature: 30-80°C (86-176°F)

Pressure: 100 kPa (1 atm)

4. Utilities - Not given

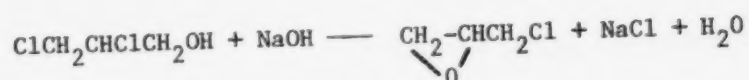
5. Waste Streams - Vent gases from the reactor may contain allyl alcohol, allyl chloride, chlorine, dichlorohydrin and reaction by products such as propylene dichloride.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 316-317.

Hancock, E. G., Propylene and Its Industrial Derivatives, John Wiley and Sons, New York, N.Y., 1973, p. 24.

Epichlorohydrin (from dichlorohydrin)

1. Function - Epichlorohydrin is commercially produced by the dehydrochlorination of dichlorohydrin. In this process, crude dichlorohydrin (see Process No. 290) is treated with a lime slurry or caustic soda in a column-type reactor at 70-100°C and atmospheric pressure. The solvent is trichloropropane.

The crude epichlorohydrin is removed from the reaction mixture as a water azeotrope by steam stripping. Final purification is accomplished by a two-column distillation train.

If the product is to be used in glycerol production, it need not be purified.

2. Input Materials

Dichlorohydrin (crude mixture)

Calcium hydroxide - 1.01 kg/kg epichlorohydrin or

Sodium hydroxide - 1.09 kg/kg epichlorohydrin

3. Operating Parameters

Temperature: <60°C (<140°F)

Pressure - 101 kPa (1 atm)

4. Utilities

Not given

5. Waste Streams

Tail gas absorber vent (air)

Chlorine - 0.5 g/Mg product  
Hydrogen chloride - 0.5 g/Mg product  
Allyl chloride - 2 kg/Mg product  
Reactor vent (air)  
Allyl chloride - 2 kg/Mg product  
Epichlorohydrin - 1.5 kg/Mg product  
Trichloropropane - 0.5 kg/Mg product  
Chlorine - 0.5 g/Mg product  
Hydrogen chloride - 0.5 kg/Mg product

The major water pollution problem would probably be a slurry containing lime or caustic soda, calcium chloride or sodium chloride, and small amounts of epichlorohydrin.

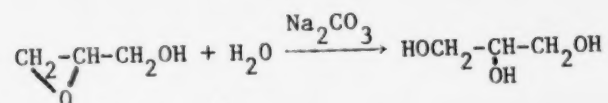
6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 131, 132.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N.Y., 1975, p. 335, 336.

Glycerol (from peroxidation of allyl alcohol)

1. Function - This process has become competitive with the hydrochlorination of allyl alcohol in the synthesis of glycerin. The trend has been away from chlorination to peroxidation because in the former process the chlorinated products are discarded, for lack of markets, while the products of hydroperoxidation are all saleable.

Allyl alcohol is epoxidized by reaction with a hydroperoxide. The hydroperoxide that is used is chosen carefully so that its degradation product is saleable or useable in an allied process. The hydroperoxides commonly used are t-butyl hydroperoxide (degradation product, t-butyl-alcohol) and ethyl benzene hydroperoxide (degradation product, phenyl methyl carbinol). The glycidol produced is hydrolyzed to produce glycerin. Although the reactants in this process are more expensive than those in the chlorohydrin-glycerin process, their cost is recoverable since all products are utilized.

2. Input Materials

Allyl alcohol - 0.67 kg/kg glycerol

t-Butyl hydroperoxide - 1.1 kg/kg glycerol

3. Operating Parameters

Temperature: 25-30°C (77-86°F)

Pressure: 1.6-3.6 KPa (16-35 atm)

4. Utilities - Not given

5. Waste Streams - Air streams may contain allyl alcohol and degradation products of the hydroperoxide (t-butyl alcohol, for example). Waste water streams may contain allyl alcohol, glycidol, sodium carbonate and t-butyl alcohol or methyl phenyl carbinol depending on the hydroperoxide used.

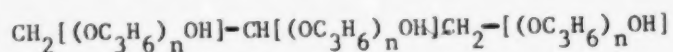
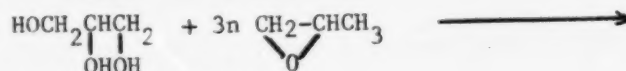
6. EPA Source Classification Code - None

7. References

R. G. Muller, "Glycerin and Intermediates," Report No. 58, Stanford Research Institute, Menlo Park, California, 1969.

"Hydrocarbon Processing," Nov. 1961, p. 249.

Hedley, W. H. et al., Potential Pollutants From Petrochemical Processes, Prepared for EPA, Final Report MRC-DA-406, Contract 68-02-0226, Dec. 1973, p. 149-150.

Glycerol Tri(polyoxypropylene) Ether (GTPE)

1. Function - Glycerol tri(polyoxypropylene) ether is formed by the base-catalyzed reaction of glycerol and propylene oxide. The conversion is normally carried out at 125°C and 446 kPa (4.4 Atm).

Near the end of the reaction, some ethylene oxide is usually added to impart certain desired properties characteristic of polyoxyethylene linkages.

GTPE is prepared in a variety of molecular weights.

2. Input Materials

Glycerol  
Propylene oxide  
Ethylene oxide

3. Operating Parameters

Temperature: 125°C (257°F)  
Pressure: 446 kPa (4.4 atm)  
Catalyst: KOH

4. Utilities - Not given.

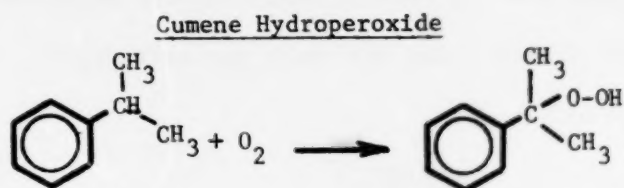
5. Waste Streams - Waste streams from purification operations are likely to contain quantities of propylene oxide, spent catalyst, glycerol, GTPE, and by-products such as propylene glycol.



6. EPA Source Classification Code - None.

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals -  
Part 6", "Chemical Engineering", May 27, 1974, p. 103.



1. Function - The hydroperoxide is made from cumene by an air oxidation process. A mixture of cumene, water, sodium carbonate, sodium stearate and a small amount of cumene hydroperoxide, which functions as an oxidation initiator, is fed to a liquid phase oxidation vessel. The oxidizing agent is air, and the reaction is carried out at 130°C and 274-446 kPa (2.70-4.40 atm) until 35-50% of the cumene is converted to the hydroperoxide. The oxidation product is distilled so that most of the unreacted cumene goes overhead, and the cumene hydroperoxide to bottom. As of January 1, 1975, almost 91% of synthetic phenol capacity was based on the acid-catalyzed cleavage of cumene hydroperoxide.

2. Input Materials

Cumene

Air

Sodium carbonate

Sodium stearate

Water

3. Operating Parameters

Temperature - 130°C (266°F)

Pressure - 274-446 kPa (2.70-4.40 atm)

4. Utilities - Not given

5. Waste Streams - Waste water contains sodium carbonate, sodium stearate, phenol and acetone. The air vents may emit cumene, acetone and traces of mesityl oxide.

|                  | <u>Plant 1</u>                                                   | <u>Plant 2</u>                                                 |
|------------------|------------------------------------------------------------------|----------------------------------------------------------------|
| Flow             | $2.33 \times 10^{-3} \text{ m}^3/\text{kg}$ (279.6 gal/1000 lbs) | $1.37 \times 10^{-3} \text{ m}^3/\text{kg}$ (164 gal/1000 lbs) |
| COD              | 4,700 mg/l<br>11.1 g/kg                                          | 84,304 mg/l<br>11.4 g/kg                                       |
| BOD <sub>5</sub> | 2,410 mg/l<br>5.6 g/kg                                           | 17,575 mg/l<br>24 g/kg                                         |
| TOC              | 194 mg/l<br>0.45 g/kg                                            | 77,406 mg/l<br>105.6 g/kg                                      |

Lower values for plant 1 due to installation of dephenolizer facilities (steam strippers).

6. EPA Source Classification Code - 3-01-034-01

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1," "Chemical Engineering," January 21, 1974, p. 130.

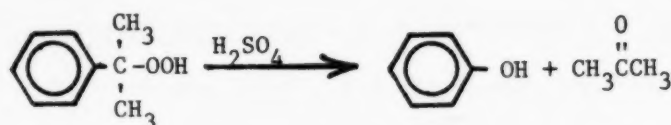
Ibid., Part 8, July 22, 1974, p. 107,108.

"1973 Petrochemical Handbook," "Hydrocarbon Processing," November 1973, p. 158.

"1975 Petrochemical Handbook," "Hydrocarbon Processing," November 1975, p. 170.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 182,183.

Phenol (decomposition of cumene hydroperoxide)

1. Function - Cumene hydroperoxide decomposes under the influence of sulfuric acid to acetone and phenol. Approximately 88% of the phenol produced in the United States in 1974 was made by this process. The hydroperoxide is usually made from crude cumene and may contain benzene and  $\alpha$ -methyl styrene.

2. Input Materials

Cumene hydroperoxide

Sulfuric acid

3. Operating Parameters

Temperature - 70-80°C (158-176°F)

Pressure - 50-152 kPa (0.5-1.5 atm)

Catalyst - Sulfuric acid

4. Utilities - Not given

5. Waste Streams

Crude Phenol surge (water)

Cumene trace

Acetone -  $4.5 \times 10^{-4}$  kg/kg phenol

Phenol -  $7.5 \times 10^{-5}$  kg/kg phenol

Evaporator Residue

Acetophenone - .00175 kg/kg phenol

Phenol -  $7.5 \times 10^{-4}$  kg/kg phenol

Polymeric matter - 0.11 kg/kg phenol

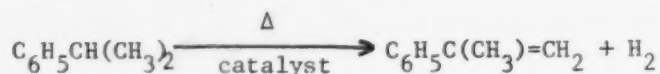
Cumyl phenol -  $8.5 \times 10^{-4}$  kg/kg phenol

6. EPA Source Classification Code - None

7. Reference

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley and Sons, New York, N.Y., 1975, pp. 612-613.

Hedley, W. H., et al., "Potential Pollutants from Petrochemical Processes,"  
for Control Systems Laboratory, NERC, Environmental Protection Agency,  
Contract No. 68-02-0226, Task No. 9, pp. 121-122.

$\alpha$ -Methylstyrene (dehydrogenation of cumene)

1. Function - Most commercial  $\alpha$ -methylstyrene is produced by the dehydrogenation of cumene. In a typical operation, a mixture of three parts steam to one part cumene is passed rapidly over an iron oxide catalyst at temperatures of 500-600°C.

The crude dehydrogenation mixture contains cumene and  $\alpha$ -methylstyrene, as well as small amounts of benzene, toluene, ethylbenzene, styrene, and tars. All of the usable components are separated and purified through a series of fractional distillations and recycled.

2. Input Materials

Cumene

Steam

3. Operating Parameters

Temperature: 550-600°C (1022-1112°F)

Pressure: not given

Catalyst: iron oxide

4. Utilities - Not given.

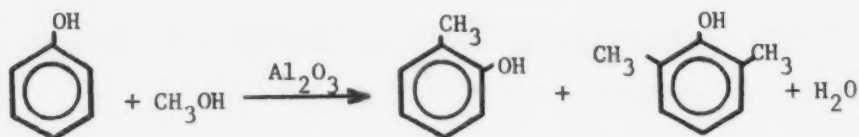
5. Waste Streams - Wastewater streams from the separators and superheater probably contain a variety of heavy-end aromatic hydrocarbons, tars, and spent catalyst. Organic solids from still bottoms are usually incinerated.

6. EPA Source Classification Code - None.

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N. Y., Vol. 19, (1969) p. 81.



2,6-Xylenol (methylation of phenol)

1. Function - 2,6-Xylenol is a by-product of the methylation of phenol to produce o-cresol. The xylenol isomer is present in approximately 25% of the yield. Phenol is reacted with methanol at about 300°C and a pressure of 4.13 MPA (41 atm) over an alumina catalyst. Small amounts of meta and para alkylated products are formed as well as some phenyl ethers formed by oxidative coupling. The crude product is separated and purified by crystallization.
2. Input Materials  
Phenol  
Methanol  
Alumina
3. Operating Parameters  
Temperature: 300°C (572°F)  
Pressure: 4.13 MPA (41 atm)  
Catalyst:  $\text{Al}_2\text{O}_3$
4. Utilities - Not given
5. Waste Streams - Air vent streams would contain methanol and small quantities of phenol. Wastewater effluents from purification operations probably contain small quantities of ethers and m- or p- substituted cresols and xylenols. Unreacted methanol and phenol may also be present in trace amounts.

6. EPA Source Classification Code - None

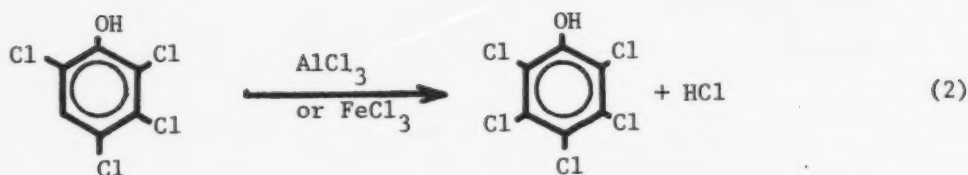
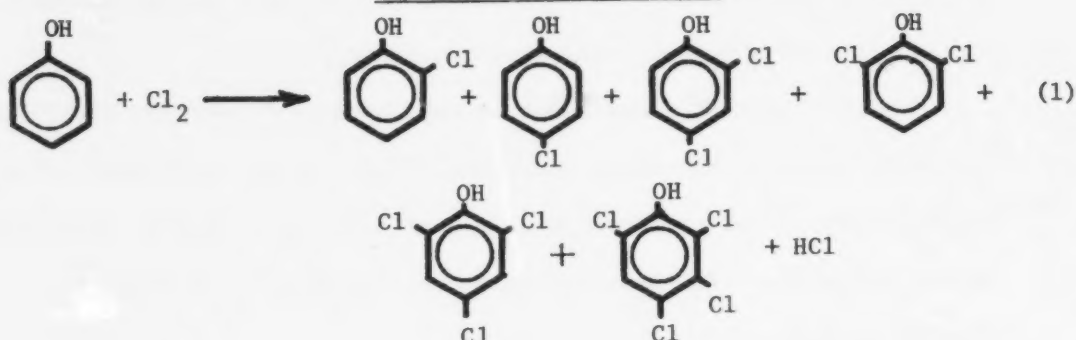
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965) p.

Hahn, A. V., The Petrochemical Industry, McGraw-Hill Book Co., New York,  
1970, p. 576-78.

## CHLOROPHENOLS

(Chlorination of phenols)



1. Function - The most widely used method for the preparation of monochlorophenols is the direct chlorination of phenol in the absence of a solvent. The product is a mixture of o- and p-chlorophenols with preponderance of the para isomer. The reaction will proceed stepwise to the di-, tri- and tetrachloro- products although the rate slows with each additional atom of chlorine added to the phenol substrate.

The dichlorophenols can be produced by direct regulated action of chlorine in a solvent such as glacial acetic acid or chloroform. Chlorination in aqueous solution gives 2,4,6-trichlorophenol rapidly and quantitatively.

Pentachlorophenol is produced by chlorinating the more highly substituted chlorophenols in the presence of  $\text{FeCl}_3$  or  $\text{AlCl}_3$  since the rate of chlorination has decreased to the point that the uncatalyzed reaction becomes prohibitably slow.

The chlorophenols can be separated from unreacted phenol by adding potassium carbonate which reacts with the chlorinated phenols to form the water-soluble salts. Phenol is not basic enough to react and can therefore be extracted from the water solution.

The chlorophenol isomers can be separated by fractional distillation. Pentachlorophenol, 2,4-dichlorophenol, 2,3,4,6-tetrachlorophenol, 2,4,6-trichlorophenol and p-chlorophenol are all soluble products. o-Chloro and 2,6-dichlorophenol have no commercial use and are recycled for further chlorination.

2. Input Materials

Phenol

Chlorine

Potassium carbonate

Aluminum trichloride or ferric chloride

3. Operating Parameters

Temperature - 50-155°C (122-311°F)

Pressure - not given

Catalyst - for pentachlorination -  $\text{AlCl}_3$  or  $\text{FeCl}_3$  (0.05-1.0%)

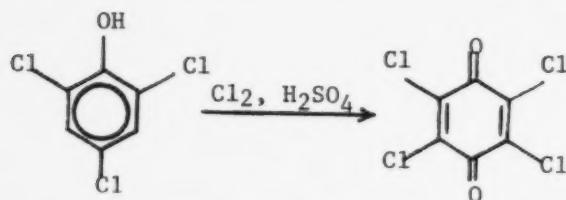
4. Utilities - Not given

5. Waste Streams - Waste water streams from washing operations and still bottoms probably contain quantities of potassium chloride, HCl, phenol chlorine and chlorophenols. Chlorine, HCl and extraction solvents are present in air emissions.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1968) p. 300.

Chloranil (from 2,4,6-trichlorophenol)

1. Function - Chloranil or 2,3,5,6-tetrachloro-1,4-benzoquinone is prepared by the action of chlorine and fuming sulfuric acid on 2,4,6-trichlorophenol.
2. Input Materials  
2,4,6-Trichlorophenol  
Chlorine  
Sulfuric acid (fuming)
3. Operating Parameters - Not given.
4. Utilities - Not given.
5. Waste Streams - Effluents from purification operations may contain 2,4,6-trichlorophenol and other chlorophenols, chlorine, sulfuric acid, chloranil and a variety of reaction by-products.
6. EPA Source Classification Code - None.
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 334.

Aniline (ammonolysis of phenol)

1. Function - Currently, the most economical route to aniline is the ammonolysis of phenol. In this process, ammonia and phenol are preheated and fed to a fixed-bed catalytic reactor where the conversion takes place over alumina. The reactor effluent is partially condensed and unconverted ammonia is compressed and recycled. The water of reaction is removed from the crude aniline stream by distillation, at the same time unreacted phenol distills as an azeotrope with water and is recycled. High purity aniline product is recovered by distillation from heavies. This process offers less by-products than other commercially used processes.
2. Input Materials  
Phenol - 1.05 kg/kg product  
Ammonia - 0.20 kg/kg product
3. Operating Parameters  
Temperature: not given  
Pressure: not given  
Catalyst: alumina
4. Utilities  
Not given
5. Waste Systems - Off-gases from the separator may contain hydrogen, nitrogen, and some ammonia. Traces of aniline and phenol may be present in the waste gas from the dryer. The rejected heavies from



the final distillation could be present in waste water streams, but are probably incinerated. Overall, waste disposal problems are considered minimal.

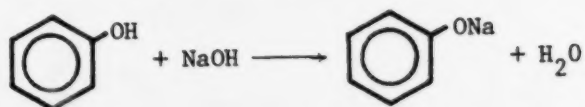
6. EPA Source Classification Code - 3-01-034-01

7. References

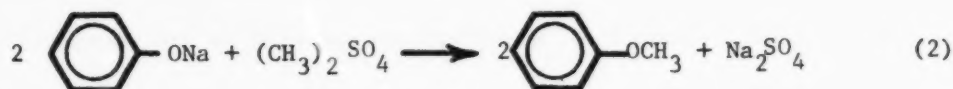
Austin, G. T., "The Industrially Significant Organic Chemicals - Part 1, "Chemical Engineering," January 21, 1974, p. 132.

"1973 Petrochemical Handbook Issue," "Hydrocarbon Processing," November 1973, p. 105.

"1975 Petrochemical Handbook", Hydrocarbon Processing," November 1975, p. 114.

Sodium Phenate

1. Function - In the commercial production of sodium phenate, phenol and a slightly greater than equimolar quantity of hot aqueous sodium hydroxide (concentration about 50%) are mixed in thermocoil autoclaves. The solution is heated to approximately 130°C and is evaporated to dryness, first at atmospheric pressure and in later stages by the application of a vacuum. This operation is sometimes carried out in heated ball mills in order to yield a dry, powdered product.
2. Input Materials  
Phenol  
50% aqueous sodium hydroxide
3. Operating Parameters  
Temperature - 130°C  
Pressure - Not given
4. Utilities - Not given
5. Waste Streams - The principal source of air pollutions in this process is the evaporation step when a mixture of water vapor and phenol is emitted.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 17 (1968) p. 148.

ANISOLE

1. Function - Anisole is made by the Williamson reaction which is the alkylation of a phenate salt. The most economical route to anisole is described by equation (1) and involves the reaction of sodium phenate and methyl chloride. An alternate method, utilized more in the past, was based on the use of dimethylsulfate as the alkylating agent (2).

In both methods, the sodium phenate is prepared in situ by combining molten phenol and sodium hydroxide at 45-60°C. The alkylating agent is added and the temperature is then increased to 100°C. The yield in both processes approximates 95%.

2. Input Materials

Phenol (2) 0.92 kg/kg anisole

Sodium hydroxide

(1) methyl chloride

(2) dimethyl sulfate

3. Operating Parameters

Temperature - 45-100°C (113-212°F)

Pressure - not given

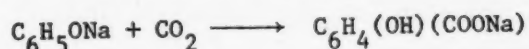
4. Utilities - not given

5. Waste Streams - Waste streams from purification processes may contain sodium chloride or sodium sulfate, depending on the process used, sodium hydroxide, phenol, sodium phenate, anisole and methyl chloride or dimethyl sulfate, depending on the process utilized. Methyl chloride may also be present in the off-gases of various processing equipment.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 15 (1968) p. 167.

Salicylic Acid and Methyl Salicylate

1. Function - In the preparation of salicylic acid, an excess of carbon dioxide at 5 - 6 atm. pressure is charged to a thermocoil autoclave containing dry, powdered sodium phenate (see Process No. 301). The conversion to sodium salicylate requires several hours at 140 - 170°C. Any regenerated phenol is recovered by vacuum distillation.

The crude product is then cooled, dissolved in water, and filtered to remove impurities. Acidification of this sodium salicylate solution with hydrochloric acid or sulfuric acid results in the precipitation of salicylic acid.

Further purification of the technical product to yield USP salicylic acid is achieved by sublimation. In order to eliminate the risk of dust explosions, caused by frictional electricity during this operation, a stream of inert gas (nitrogen with some carbon dioxide) is circulated through the sublimation chamber. The products obtained are USP salicylic acid and a slightly colored technical grade sublimed acid. The yields of technical-grade and USP salicylic acid from this entire process are 88% and 84%, respectively.

Methyl salicylate is an important commercial product in the perfume and flavoring industries. Production in 1972 was in excess of 5,000,000 pounds. It is produced from salicylic acid, which has been purified by sublimation, by esterification with methyl alcohol in the presence of catalytic amounts of sulfuric acid. The ester product is purified by vacuum distillation with the water and unreacted methanol recycled to the system.

2. Input Materials

Sodium phenate (from phenol - 0.74 kg/kg salicylic acid)

Carbon dioxide

Water

Hydrochloric acid or sulfuric acid

Nitrogen

3. Operating Parameters

Temperature: carboxylation - 140 - 170°C (252 - 338°F)

acidification - not given

Pressure: carboxylation - 500 - 600 kPa (5-6 atm)

acidification - not given

4. Utilities

Based on production of 4,000 pounds of salicylic acid/day

Steam - 0.158 kg/sec (1,250 lb/hr)

Power - 3,600 MJ (1,000 kWh)

5. Waste Streams - The principal pollutant source in this process should be the waste water stream from centrifuging operations. The mother liquor is likely to contain sodium chloride or sulfate, hydrochloric or sulfuric acid, various reaction by-products, and traces of phenol and salicylic acid.

The wash water stream contains salicylic acid, sulfuric acid and methanol. The vent streams from the esterification and distillation steps will contain some methanol.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 17, (1968), p. 723-25.

"Phenol," in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, California.

Shreve, R. N., Chemical Process Industries, 3rd Edition, McGraw Hill Book Company, New York, N. Y., 1956, p. 864.

Groggins, Unit Processes in Organic Synthesis, 5th Edition, McGraw Hill Book Company, New York, N.Y., 1958, p. 367.



Cyclohexanol (hydrogenation of phenol)

1. Function - Some cyclohexanol is produced by the catalytic hydrogenation of phenol. The reaction takes place over active nickel at 70-80°C and elevated pressure.

Cyclohexanone is a by-product of this reaction, and may be removed by condensation with benzaldehyde in the presence of alkali.

2. Input Materials

Phenol

Hydrogen

Benzaldehyde

Alkali

3. Operating Parameters

Temperature: 70-80°C (126-176°F)

Pressure: not given

Catalyst: activated nickel

4. Utilities - Not given

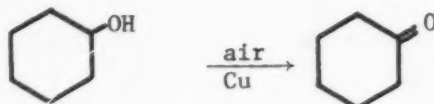
5. Waste Streams

Some phenol, cyclohexanol, and cyclohexanone may be present in air emissions from purification processes. Wastewater streams, if present, may contain alkali, benzaldehyde, cyclohexanone, and condensation products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 684.

Cyclohexanone (oxidation of cyclohexanol)

1. Function - Small quantities of cyclohexanone may be produced by passing cyclohexanol over copper catalyst with air at 140°C.

2. Input Materials

Cyclohexanol

Air

3. Operating Parameters

Temperature - 140°C

Pressure - Not given

Catalyst - Copper

4. Utilities - Not given

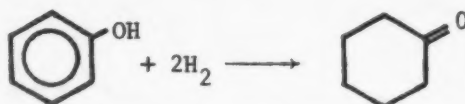
5. Waste Streams - Waste water streams contain sodium hydroxide and dissolved organics. Light ends column vent emits cyclohexane, cyclohexanol and cyclohexanone.

6. EPA Source Classification Code - None

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Final Report, Contract 68-02-0226, Task 9, December 1973, p. 224.

Waddams, A. L., Chemicals from Petroleum, 3rd Ed., John Murray Ltd., London, England, 1973, p. 136.

Cyclohexanone (hydrogenation of phenol)

1. Function - Some cyclohexanone is produced by a hydrogenation reaction similar to that employed to make cyclohexanol from phenol. The distinguishing variation is the milder catalyst used in this process.

Phenol and hydrogen are fed to a hydrogenator, where they are reacted in the liquid phase at 100-200°C and 1-4 atm pressure in the presence of a palladium-on-carbon catalyst. After scrubbing and cooling, the reaction mixture is removed to a distillation column, where high boilers are removed and cyclohexanone is recovered. This method accounts for approximately 20% of the total of cyclohexanone produced commercially in the United States.

2. Input Materials - Basis kg cyclohexanone

Phenol - 1.005 kg

Hydrogen - 0.64 m<sup>3</sup>

Palladium-on-charcoal - small

3. Operating Parameters

Temperature - 100-200°C (212-392°F)

Pressure - 101-404 kPa (1-4 atm)

Catalyst - Palladium-on-charcoal

4. Utilities - Not given

5. Waste Streams - Air vent systems contain some hydrogen. Waste water from the scrubber will contain phenol, small quantities of cyclohexanol and cyclohexanone. Vents from the overhead take-off system in the distillation process will emit cyclohexanol and cyclohexanone.

6. EPA Source Classification Code - None

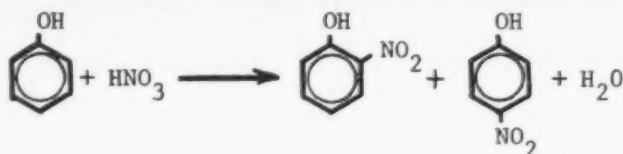
7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 3," "Chemical Engineering," March 18, 1974, p. 92.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 6 (1965), p. 686.

Waddams, A. L., Chemicals From Petroleum, 3rd Edition, John Murray, London, England, 1973, p. 136.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, Inc., 1975, p. 306-307.

o- and p-Nitrophenols (from phenol)

1. Function - Some o- and p-nitrophenol is produced by the nitration of phenol with dilute nitric acid at low temperatures. The presence of an OH group on the ring activates it and permits a significant amount of oxidation resulting in a relatively large proportion of by-products. The nitration produces the ortho-isomer in about a 4x excess. The overall yield however, is 40% ortho, 13% meta, 14% para, and 33% oxidation products. The more volatile ortho isomer is almost quantitatively stripped from the crude product by steam distillation. The residue is heated and recrystallized in dilute acid to obtain the para isomer.

2. Input Materials

Phenol - for o-nitrophenol - 1.69 kg/kg product  
for p-nitrophenol - 5.20 kg/kg product  
total product - 1.28 kg/kg product

Nitric acid (20% aqueous)

3. Operating Parameters

Temperature -  $-20^{\circ}\text{C}$  ( $-68^{\circ}\text{F}$ )

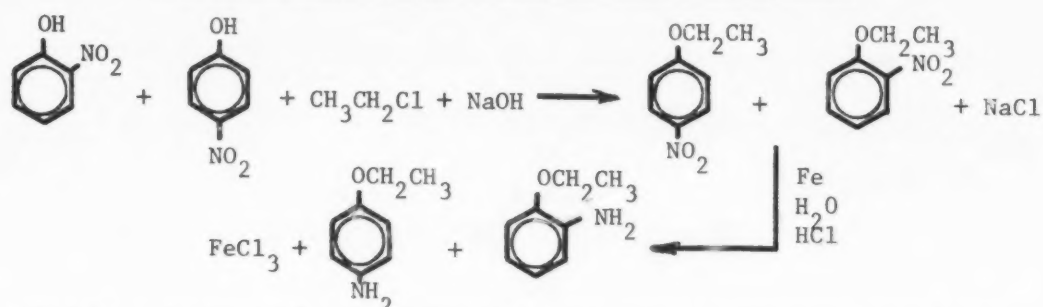
Pressure - 101 kPa (1 atm)

4. Utilities

Not given

5. Waste Streams - Process waste effluents probably contain a variety of resinous by-products, dinitrophenols and trinitrophenols, oxalic acid, nitric acid, phenol, and small amounts of p-nitrophenol.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 892, 893.



o- And p-Phenetidine (from o- and p-nitrophenol)

1. Function - Ortho- and para-phenetidine are usually prepared from nitrophenol isomers by ethylation (Williamson Reaction) and reduction. The initial step is the formation of the ethyl-phenyl ether by the displacement of chloride from the ethyl chloride by the o- or para-nitrophenate ion. Either ethyl chloride or diethyl sulfate may be used as the alkylating agent.

The nitrated phenol ether is then reduced to the corresponding amine using iron turnings and hydrochloric acid as the reducing system.

2. Input Materials

o- and p-Nitrophenol

Ethyl sulfate or ethyl chloride

Sodium hydroxide

Hydrochloric acid

Iron filings

Water

3. Operating Parameters

Alkylation

Temperature - 20-30°C (68-86°F)

Pressure - 101 kPa (1 atm)

Reduction

Temperature - 200°C (392°F)

Pressure - 101 kPa (1 atm)

4. Utilities

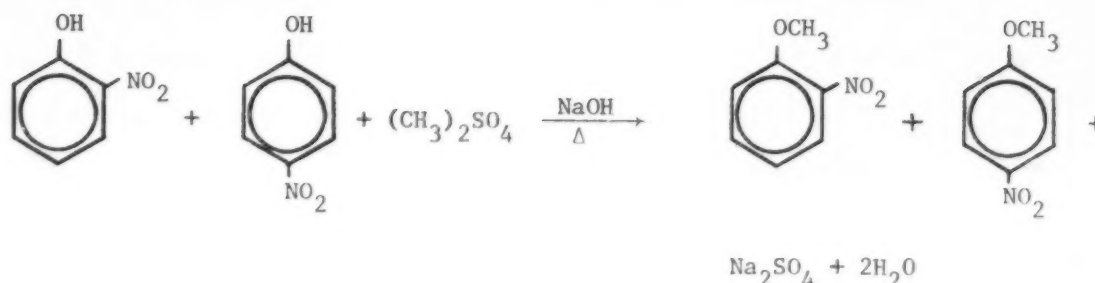
Not given

5. Waste Streams - Aqueous wastes from separation probably contain sodium chloride, ethyl chloride, ethyl alcohol, nitrophenol and phenetidine isomers, and a variety of reduction by-products. Ethyl chloride, ethyl alcohol, and HCl may be discharged from reactor vents and various types of purification equipment.

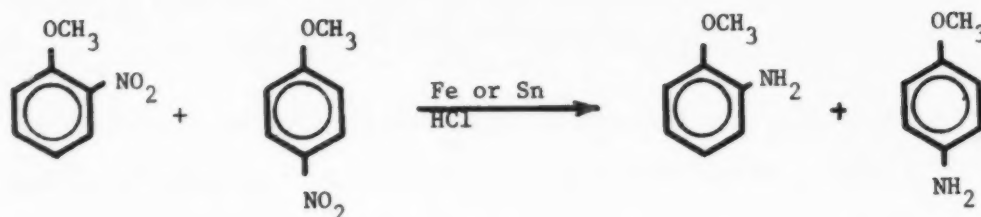
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 422, 423.

Nitroanisoles (from nitrophenol)

1. Function - The o- and p-isomers of nitroanisol are produced by methylating the corresponding isomers of nitrophenol with a reagent such as dimethyl sulfate. The reaction is carried out in hot aqueous sodium hydroxide.
2. Input Materials
  - o- and p-Nitrophenol
  - Dimethyl sulfate
  - Sodium hydroxide
  - Water
3. Operating Parameters - not given
4. Utilities - not given
5. Waste Streams - Air and water effluents from separation probably contain quantities of sodium hydroxide and sodium sulfate (water only), dimethyl sulfate, and reaction by-products such as methanol.
6. EPA Source Classification Code - None
7. References
  - Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 15 (1968), p. 148, 168.

ANISIDINE(reduction of nitroanisole)

1. Function - Ortho- and para-anisidines are produced from o- and p-nitroanisole by reduction with tin or iron filings and hydrochloric acid.

The ortho and para isomers are separated by steam distillation.

2. Input Materials

o- and p-Nitroanisole

Hydrochloric acid

Tin or iron filings

3. Operating Parameters

Not given

4. Utilities

Not given

5. Waste Streams - Liquid and/or solid wastes from purification may contain iron or tin salts and other reaction by-products.

6. EPA Source Classification Code - 3-01-034-01

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,

Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 422.

Nonylphenol

1. Function - Nonylphenol is commercially prepared by the alkylation of phenol with a mixture of isomeric nonylenes (propylene trimers). The reaction is carried out at 50-100°C and 345 kPa (3.4 atm) in the presence of boron trifluoride catalyst.

The conversion takes place in the liquid phase and yields a mixture of isomers, mostly para- with some 2,4-dinonyl substitution. Both continuous and batch processes are used.

Following alkylation, the crude product is washed several times and heated under vacuum to remove traces of reactants and water. The final purification step is a vacuum distillation at 10-20 mm Hg.

2. Input Materials

Phenol - 0.46 kg/kg product

Nonene - 0.76 kg/kg product

3. Operating Parameters

Temperature: 50-100°C (122-212°F)

Pressure: 345 kPa (3 atm)

Catalyst:  $\text{BF}_3$

4. Utilities - Not given.

5. Waste Streams - The main source of pollution is the wastewater from the product washing step. The water contains spent catalyst, phenol, and traces of product.

6. EPA Source Classification Code - None

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7", "Chemical Engineering", June 24, 1974, p. 155.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 908.

Octylphenol

1. Function - Octylphenol is prepared by alkylating phenol with isobutylene dimer. The product is a mixture of isomers.

The reaction conditions and purification procedures are similar to those used in nonylphenol production.

2. Input Materials

Phenol

Diisobutylene

$\text{H}_2\text{SO}_4$

3. Operating Parameters

Temperature: 120°C (248°F)

Pressure: Not known

Catalyst:  $\text{H}_2\text{SO}_4$

4. Utilities - Not given.

5. Waste Streams - The principal waste stream from this process is the product wash water. This may contain phenol, sulfuric acid and traces of octylphenol.

6. EPA Source Classification Code - None.

7. References

Goldstein, R. F., The Petroleum Chemicals Industry, John Wiley and Sons, Inc., New York, N.Y., 1958, p. 191-2.

Chemical Technology, Barnes and Noble Books, New York, N.Y.,

Vol. 4 (1972), p. 149.



Dodecylphenol

1. Function - Dodecylphenol is produced from phenol and propylene tetramer (dodecene), and consists mainly of a mixture of p-alkylphenols derived from various isomeric branched-chain dodecylenes.

The alkylation process is quite similar to that used to make nonylphenol.

2. Input Materials

Phenol - 0.38 kg/kg product

Dodecene - 0.86 kg/kg product

3. Operating Parameters

Temperature: 50-100°C (122-212°F)

Pressure: 345 kPa (3 atm)

Catalyst:  $\text{BF}_3$

4. Utilities - Not given.

5. Waste Streams - The main source of pollution is the waste water from the product washing step. The water contains spent catalyst, phenol and traces of dodecylphenol.

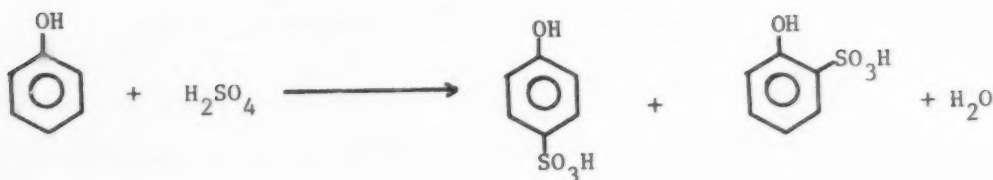
6. EPA Source Classification Code - None.

7. References

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 7", "Chemical Engineering", June 24, 1974, p. 155.

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 1 (1963), p. 908.

Phenolsulfonic Acids (from phenol)

1. Function - Phenolsulfonic acid is commercially prepared by the direct sulfonation of phenol with concentrated sulfuric acid at  $100^\circ\text{C}$ .

The yield based on phenol is approximately 94%. Although the p-isomer predominates (96%), some o-phenolsulfonic acid is also produced.

2. Input Materials

Phenol - 0.57 kg/kg product

Sulfuric acid (conc.) - 0.60 kg/kg product

3. Operating Parameters

Temperature:  $100^\circ\text{C}$  ( $212^\circ\text{F}$ )

Pressure: Not given

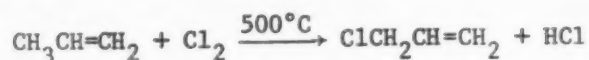
4. Utilities - Not given.

5. Waste Streams - The principal pollutant from this process should be spent caustic, present in the waste water from caustic washing operations.

6. EPA Source Classification Code - None.

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 15 (1968), 211 and Vol. 19, (1969) p. 311-18.

Allyl Chloride

1. Function - Allyl chloride is made by chlorinating propylene at 400-500°C. At temperatures of 300°C and less, addition to the double bond is the predominant reaction and 1,2-dichloropropane is formed.

The reaction is carried out in an adiabatic reactor designed to provide rapid and intimate mixing. The reaction temperature is controlled by balancing the mole ratio of the feed (usually 4 moles of propylene to one mole of chlorine) and the propylene preheat temperature. The commonly used temperature range is 500-510°C, at 200 kPa (1.9 psig).

2. Input Materials

Propylene - 723 kg/Mg product (71%)

Chlorine - 1.323 Mg/Mg product (70%)

3. Operating Parameters

Temperature: 500-510°C (932-950°F)

Pressure: 200 kPa (1.97 atm)

4. Utilities

Not given

5. Waste Streams

Absorber vent (air)

Propylene - 13.5 kg/Mg product

Ethyl chloride - 13.5 kg/Mg product

The water pollution source from the allyl chloride process would probably be spent caustic from the absorber.

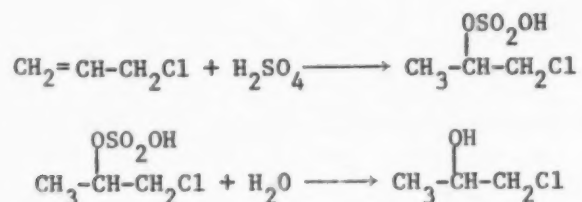
6. EPA Source Classification Code - None

7. References

Anon., "Air Pollution from Chlorination Processes," prepared for OPA, Environmental Protection Agency, Contract No. CPA 70-1, March 1972.

Muller, R. G., "Glycerine and Intermediates," Report No. 58, Stanford Research Institute, Menlo Park, California, 1969.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N.J., 1974, p. 75,76.

Propylene Chlorohydrin (from allyl chloride)

1. Function - Small quantities of propylene chlorohydrin are produced by the acid catalyzed hydration of allyl chloride. This system yields 1-chloro-2-propanol free of 2-chloro-1-propanol.
2. Input Materials  
Allyl chloride  
Water  
Sulfuric acid
3. Operating Parameters  
Temperature - 3.55-4.56 MPa (35-46 atm)  
Pressure - 170-240°C (338 - 464°F)  
Catalyst - sulfuric acid
4. Utilities  
Not given
5. Waste Streams - Although no specific information was available, wastewater streams from the purification section may contain traces of sulfuric acid, allyl chloride, and propylene chlorohydrin.
6. EPA Source Classification Code - None

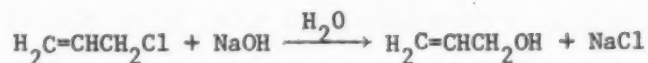
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 310.

G. Frosberg and L. Smith, Acta Chem. Scand., 1, 578 (1947).

Hancock, E. G., Propylene and Its Industrial Derivatives, John Wiley  
and Sons, New York, N.Y., 1973, p. 225.



Allyl Alcohol (from allyl chloride)

1. Function - Some allyl alcohol is prepared from propylene glycol.

One competitive route to allyl alcohol involves the hydrolysis of allyl chloride with dilute (5%) caustic solution. The reaction is run at 150-160° C and a pressure of 1.38 MPa (14 atm).

The alcohol is recovered by injecting steam to form the water-allyl alcohol azeotrope. The water is removed by ternary allyl ether azeotrope. A second distillation then yields pure allyl alcohol. The principal by-product is allyl ether which can be minimized by the addition of dilute caustic solution at a rate such that the pH is maintained in the range 8-11.

2. Input Materials

Allyl chloride

Sodium hydroxide (5% aqueous solution)

Allyl ether

3. Operating Parameters

Temperature: 150-160° C (302-320°F)

Pressure: 1.38 MPa (14 atm)

4. Utilities

Not given

5. Waste streams - The principal pollutant sources in this process are probably distillation waste water and solvent handling. Allyl chloride and allyl alcohol, as well as diallyl ether, may

be involved. Spent caustic waste streams from the reactor may also contain allyl chloride and allyl alcohol.

6. EPA Source Classification Code

None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 1 (1963), p. 588.

Fanbaun, A. W., H. A. Cheney and A. J. Charniavsky, Chem. Eng. Prog., 43, 280, (1947).

U.S. Patent 2,318,033.

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Corp., New York, N.Y., 1956, p. 196-197.

Glycerol (from allyl chloride via allyl alcohol)

1. Function - Some glycerol is produced from allyl chloride via preliminary hydrolysis to allyl alcohol (see Process No. 317). The allyl alcohol is then chlorohydrinated with aqueous chlorine solution to yield a mixture of monochlorohydrins.

The chlorohydrin intermediates are converted to glycerol in 90% yield (based on allyl alcohol) by hydrolysis with sodium hydroxide:



The crude product is a dilute aqueous solution containing 5% or less of glycerol. To obtain a high purity product, the crude mixture is first concentrated to about 80% glycerol in multiple-effect evaporators. Salt produced by the reaction is removed by centrifuging. Additional concentration of the product, followed by final desalting, yields 98% glycerol. Finally, colored substances are removed by solvent extraction and the product is refined by steam-vacuum distillation.

2. Input Materials

Allyl alcohol - 0.70 kg/kg product  
Chlorine  
Water  
Sodium bicarbonate 10% aqueous solution

3. Operating Parameters

Temperature: hydrochlorination - 14°C (57.2°F)  
hydrolysis - 150°C (302°F)

Pressure: hydrochlorination - 100 KPa (1 Atm)  
hydrolysis - elevated

4. Utilities - Not given

5. Waste Streams - The vents from the acid scrubber may omit hydrogen chloride and chlorine. Waste water will contain some sodium salts, allyl alcohol and acids.

6. EPA Source Classification Code - None.

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 10, (1966) p. 624.

Glycerol (from epichlorohydrin)

1. Function - The production of glycerol from epichlorohydrin involves a series of three reactions carried out at 157-180°C and 1.14 MPa (11.2 Atm). First, epichlorohydrin is hydrated to monochlorohydrin in basic solution.

Glycerol chlorohydrin is then dehydrochlorinated to glycidol by treatment with caustic.

In the final reaction, glycidol is hydrated to glycerol.

Pipe reactors are used in this process with residence times of 7-9 minutes. The crude glycerol product is purified in the manner described in Process No. 318

2. Input Materials

Epichlorohydrin - 1.05 kg/kg product  
 Sodium hydroxide - 0.49 kg/kg product  
 Sodium carbonate - 73.0 g/kg product  
 Toluene - 6.0 g/kg product  
 HCl - 83.5 g/kg product

3. Operating Parameters

Temperature: 157-180°C (315-356°F)  
 Pressure: 1.14 MPa (11.2 Atm)  
 Residence time: 420-540 sec.

4. Utilities - Basis: 0.361 kg/sec capacity (25.2  $\bar{M}$  lb/yr)

Cooling water - 124 dm<sup>3</sup>/sec (1960 gpm)

Power - 547.2 MJ (152 kWh)

Steam (300 psi) - 4.10 kg/sec (32,520 lb/hr) (2.07 MPa)

Process water - 3.03 dm<sup>3</sup>/sec (48 gpm)

5. Waste Streams -

Glycerol purification section - second effect evaporator (water)  
Glycerol - 4.5 kg/Mg product

Glycerol purification section - centrifuge (solid)  
Sodium chloride - 431 kg/Mg product

Glycerol purification section - centrifuge (solid)  
Sodium chloride - 431 kg/Mg product

Glycerol purification section - film evaporator (water)  
Glycerol - 9.5 kg/Mg product  
Sodium chloride - 82.5 kg/Mg product  
Miscellaneous impurities - 61 kg/Mg product

Glycerol purification section - toluene recovery column (water)  
Toluene - 4.5 kg/Mg product

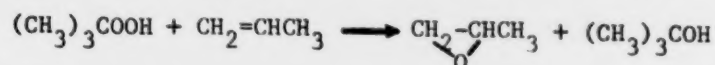
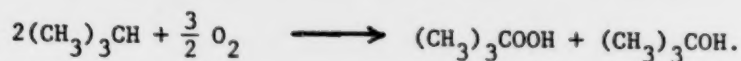
Glycerol purification section - light ends column (water)  
Glycerol - 0.95 kg/Mg product  
Toluene - 1.55 kg/Mg product

6. EPA Source Classification Code - None.

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N. Y., Vol. 10 (1966), p. 624.

Propylene Oxide (peroxidation of propylene)

1. Function - Increasing quantities of propylene oxide are now being produced by the peroxidation of propylene. The organic peroxygen carrier is usually t-butyl hydroperoxide, formed by the liquid-phase air oxidation of isobutane at 125-150°C and 3.55 MPa (35 Atm) in the presence of soluble molybdenum catalysts.

t-Butyl alcohol is the principal by-product of this reaction and also functions as a product.

After separation, the t-butyl hydroperoxide is used to oxidize propylene to propylene oxide and is reduced in the process to t-butyl alcohol. Tungsten, vanadium, or molybdenum catalyst systems catalyze this liquid-phase epoxidation.

It has been reported that the yield of propylene oxide from propylene is about 93% of the theoretical. However, this process yields considerably more t-butyl alcohol than propylene oxide (2.2 kg/kg propylene oxide).

2. Input Materials

Propylene - 0.78 kg/kg propylene oxide

Isobutane ~ 3 kg/kg product

Air



3. Operating Parameters

Temperature: isobutane oxidation - 125-150°C (257-302°F)  
epoxidation - not given

Pressure: isobutane oxidation 3.55 MPa (35 Atm)  
epoxidation - not given

Catalyst: tungsten, vanadium, or molybdenum ( $[\text{Mo}(\text{CO})_6]$  systems)

4. Utilities - 100 kg/sec capacity (70  $\bar{\text{M}}$  lb/yr)

Cooling water - 1.89  $\text{m}^3/\text{sec}$  (30,000 gpm)

Refrigeration - 454 Mg (500 tons)

Electricity - 3600 MJ (1000 kW)

Steam - 12.6 kg/sec (100,000 lb/hr) at 4.14 MPa (40.8 Atm)

Inert gas - 23.6  $\text{sdm}^3/\text{sec}$  (300 scfh)

5. Waste Streams

Hydroperoxide preparation section - absorber (air)

Isobutane - 3.5 kg/Mg product

n-Butane - 0.5 kg/Mg product

Propylene oxide recovery section - vent from vaporizing  
column (air)

Propylene - 10 kg/Mg product

Solvent recovery section - evaporator waste (liquid and  
(solid)

Toluene - 1.0 kg/Mg product

Heavy ends - 50.0 kg/Mg product

Propylene oxide purification section - off gas from column to  
flare (air)

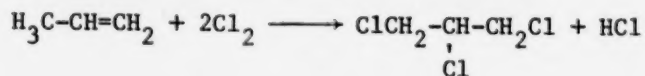
Ethylene oxide - 2.0 kg/Mg product

Acetaldehyde, etc. - 3.5 kg/Mg product

6. EPA Source Classification Code - None.

7. References

Hedley, W. H., et al., Potential Pollutants from Petrochemical Processes, Technomic Publishing Co., 1975.

1,2,3-Trichloropropane (from propylene)

1. Function - 1,2,3-Trichloropropane is made by chlorinating propylene at low temperature (25-40° C). The principal product of this reaction is propylene dichloride. In the absence of a catalyst however 20 percent of the product is 1,2,3-trichloropropane. The products are easily separated by distillation.
2. Input Materials  
Propylene  
Chlorine  
Propylene dichloride
3. Operating Parameters  
Temperature: 25-40° C (77-104°F)  
Pressure: 100 KPa (1 atm)
4. Utilities - Not available
5. Waste streams - Overhead gas streams contain chlorine, propylene, hydrogen chloride some propylene dichloride.
6. EPA Source Classification Code - None
7. References  
Astle, M. J., The Chemistry of Petrochemicals, New York, N.Y., Reinhold Publishing, 1956, p. 60-62.

Propylene Dichloride

1. Function - Propylene dichloride is produced as a by-product of the propylene chlorohydrin process for the synthesis of glycerin. Some may also be produced as a by-product of the chlorination of propylene to produce allylchloride. Propylene dichloride does not itself have industrial uses however it may be easily cracked to produce carbon tetrachloride and perchloroethylene.

The chlorine necessary to react with the propylene is present as a result of the equilibrium  $\text{HOCl} + \text{HCl} \rightleftharpoons \text{Cl}_2 + \text{H}_2\text{O}$ . The formation of propylene dichloride is promoted when the olefin concentration in the propylene chlorohydrin process falls too low or when the chlorohydrin concentration exceeds 5-6% in the system. Under the usual operating conditions 0.1 kg of propylene dichloride is formed per kg of propylene oxide.

2. Input Materials

Propylene

Chlorine

Water

3. Operating Parameters

Temperature: 30-40° C (86-104°F)

Pressure: 100 KPa (1 atm)

4. Utilities\*

|               |                                      |
|---------------|--------------------------------------|
| Cooling water | 259dm <sup>3</sup> /sec (4100 gpm)   |
| Nitrogen      | 23.6 dm <sup>3</sup> /sec (3000 cfh) |
| Power         | 648 MJ (180 KW)                      |
| Refrigeration | 1.109 Gg (1222 tons)                 |
| Steam         | 7.31 Kg/sec (58,000 lb/hr)           |

5. Waste Streams\* - Propylene dichloride is a by-product of propylene chlorohydrin production and as such the waste streams will be identical to this process. Air vent streams contain propylene and chlorine. Waste water contains HCl, HOCl, some chlorohydrin.

6. EPA Source Classification Code - None.

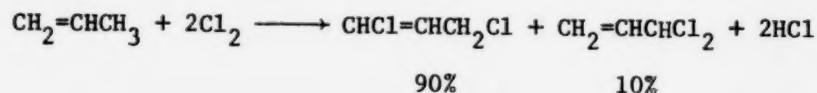
7. References

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Murray, London, 1973, p. 137-138.

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Corp., New York, 1956, p. 60-61.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 5 (1964), p. 2-3.

\*See propylene chlorohydrin waste streams.

Dichloropropenes

1. Function - 1,3-Dichloropropene and 3,3-dichloropropene are the chief secondary products of allyl chloride manufacture, which involves the high-temperature reaction of propylene and chlorine.

The dichloropropene yield may be increased by using an excess of chlorine or smaller amounts of propylene. Chlorination at temperatures below 300°C yields the addition product, 1,2-dichloropropane.

The reaction is carried out in the vapor phase under conditions similar to those used in the production of allyl chloride, temperature 500-510°C (932-950°F) and 142-284 kPa (1.4-2.8 atm). The propylene is preheated to 250-350°C (482-662°F) to prevent the addition of chlorine to the double bond on mixing. The product ratio can be controlled to some extent by the ratio of reactants charged. The use of excess chlorine to increase the product ratio of 1,3-dichloropropene to allyl chloride is limited, however, by the possibility of over chlorination of the propylene.

The product mixture is separated by passing the effluent gas stream into an HCl absorption column. Next the gas is passed into an organic absorbing solvent to remove propylene. The chlorinated propylenes are separated by fractional distillation.

2. Input Materials - Basis - 1 kg product

Propylene - 0.723 kg/kg

Chlorine - 1.32 kg/kg

3. Operating Parameters

Temperature: preheater - 340°C (650°F)

reactor - 500-510°C (932-950°F)

Pressure: 142-284 kPa (1.4-2.8 atm)

4. Utilities - Not given

5. Waste Streams - The principal sources of pollution are the air vent stream on the absorber which may emit propylene and the waste water from the absorber which contains spent caustic.

6. EPA Source Classification Code - None

7. References

Astle, M. J., The Chemistry of Petrochemicals, Reinhold Publishing Corp., New York, 1956, p. 60-61.

Hedley, W. H., et al., "Potential Pollutants from Petrochemical Processes," prepared for Control Systems Laboratory, NERC, Environmental Protection Agency, Contract No. 68-02-0226, Task No. 9, 1973, p. 136.



SECTION IX  
TOLUENE

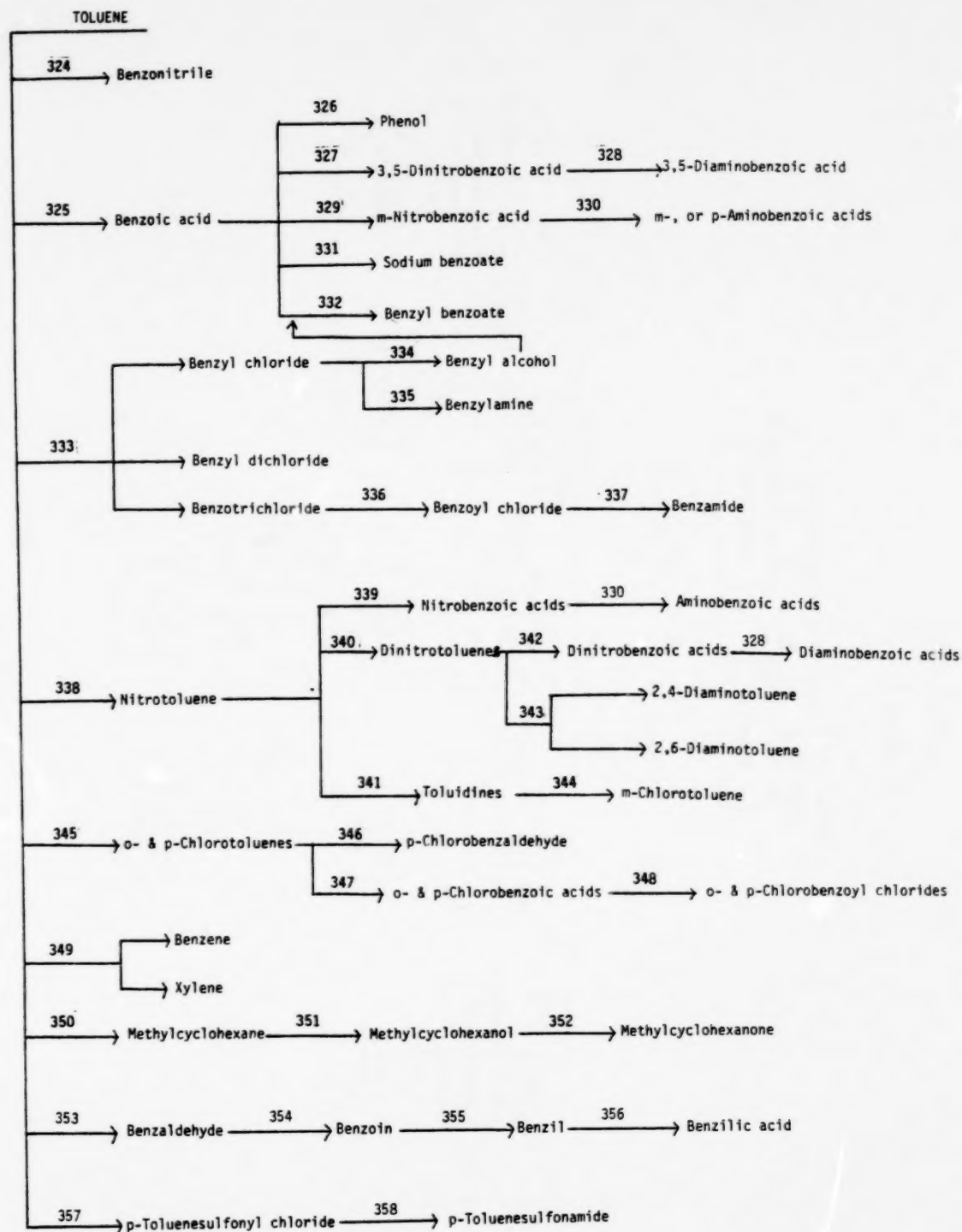


Figure 17. Toluene Section Chemical Tree

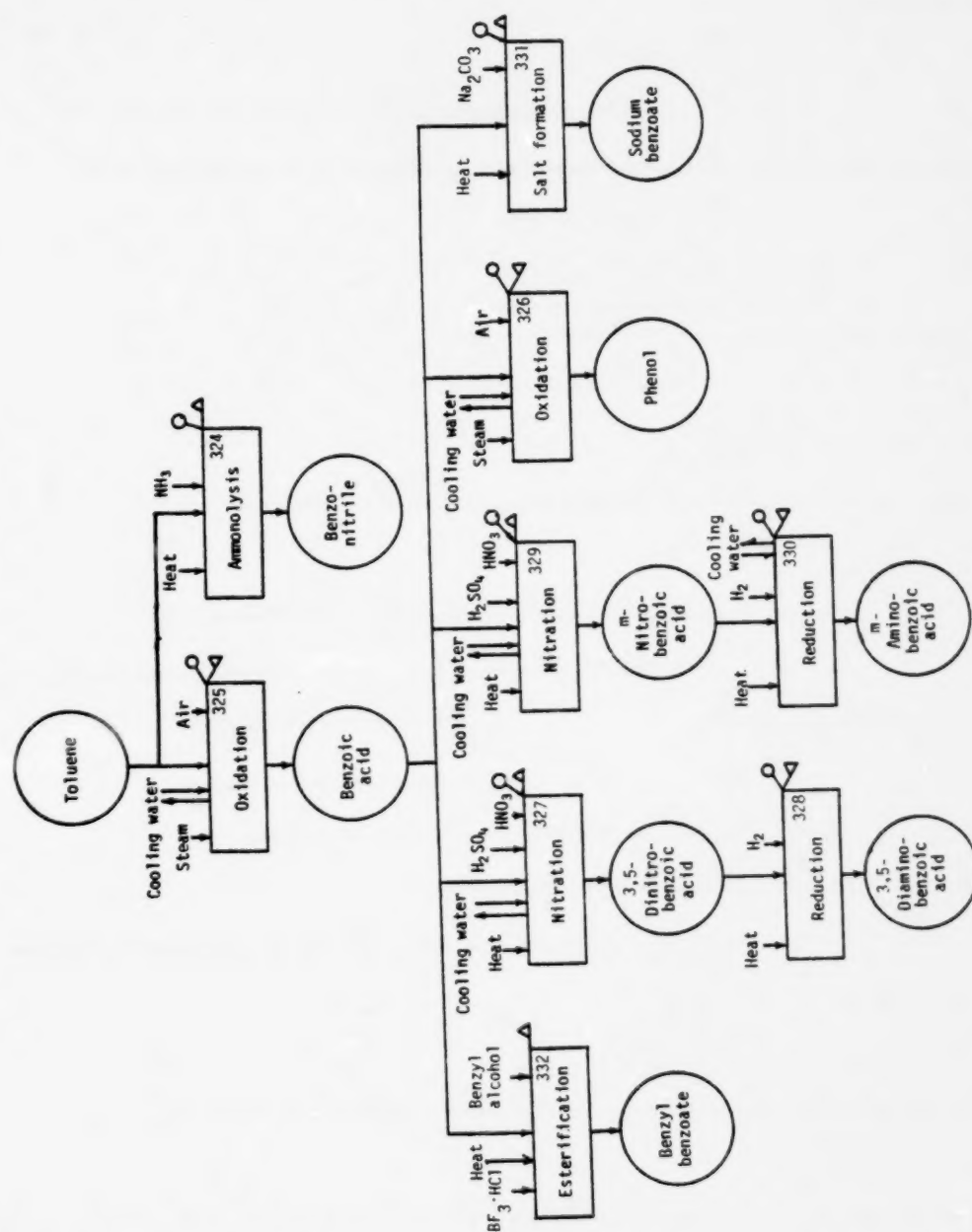


Figure 18. Toluene Section Process Flow Sheet

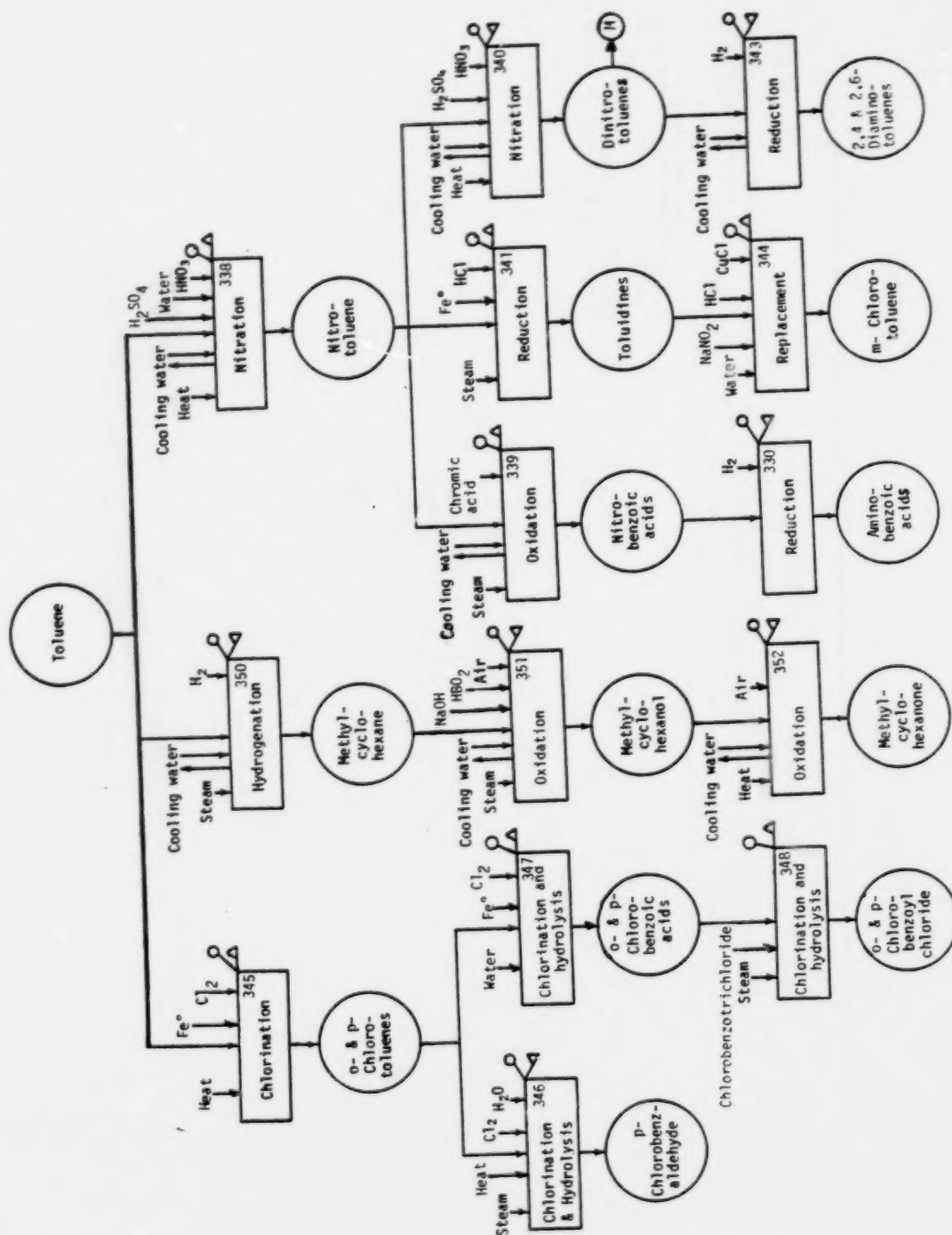


Figure 18. Toluene Section Process Flow Sheet (Cont.)

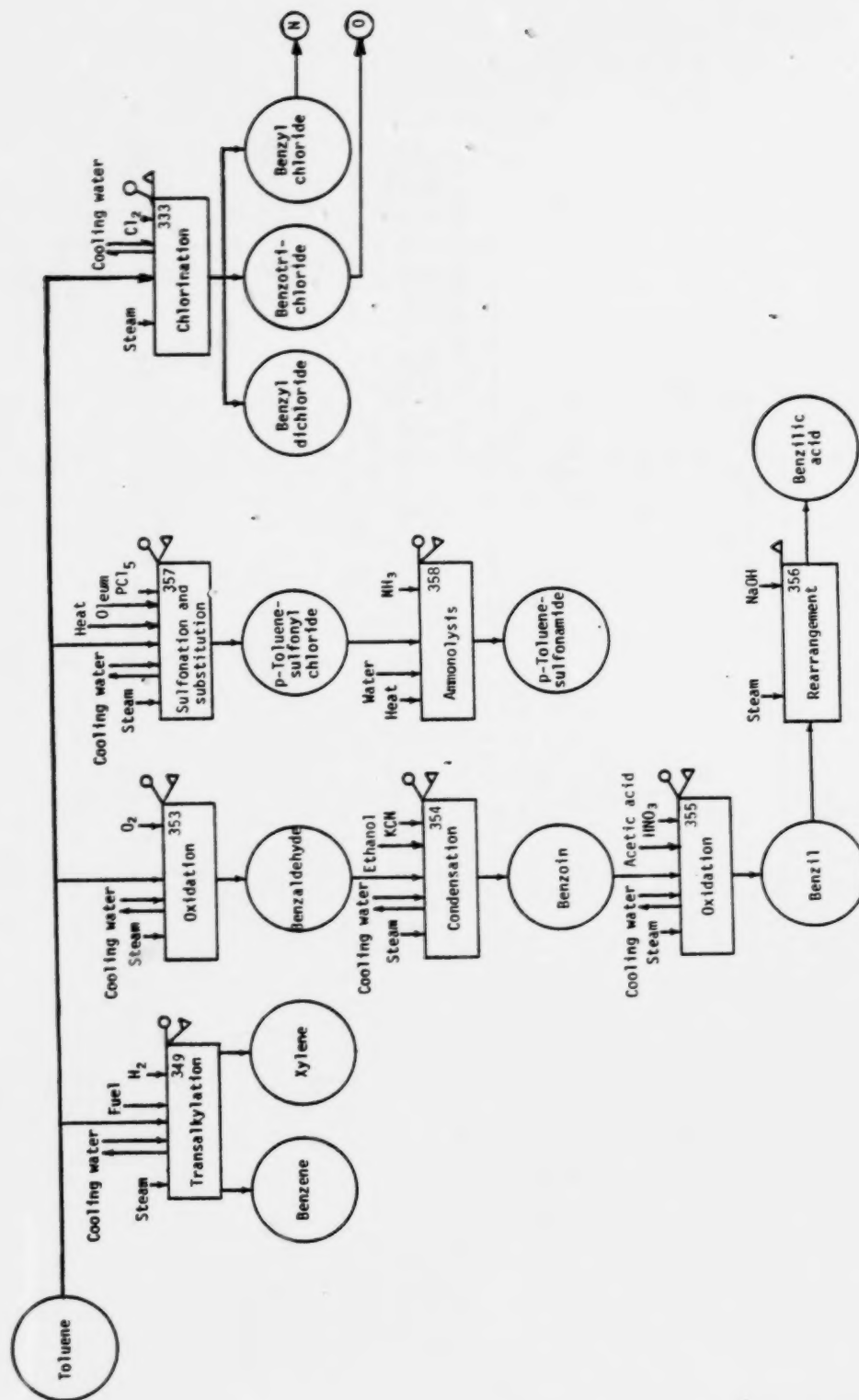


Figure 18. Toluene Section Process Flow Sheet (Cont.)

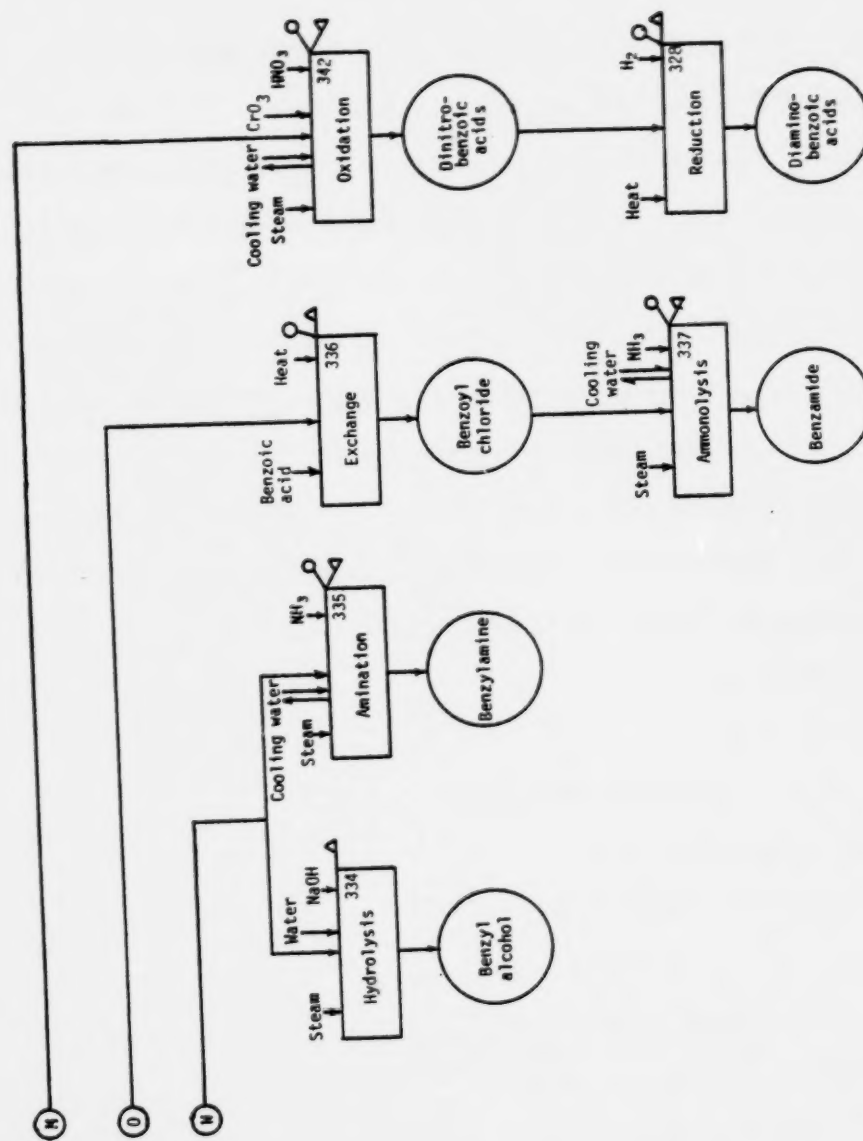
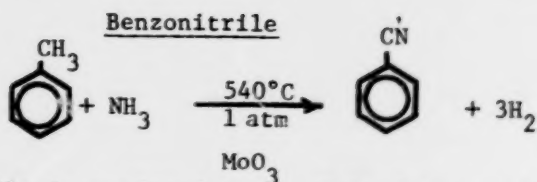


Figure 18. Toluene Section Process Flow Sheet (Cont.)

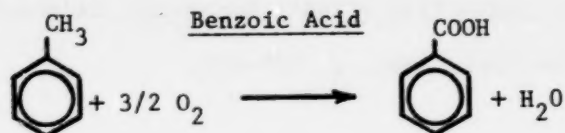


1. Function - Benzonitrile is produced in the United States chiefly by the ammonolysis of toluene in the vapor phase. The reaction takes place in a reactor that consists of a shell containing a catalyst chamber heated with a heat transfer medium from outside the shell. Benzonitrile produced in each pass is stripped from the exit gases which are recycled with makeup toluene and ammonia. The optimum operating conditions are described as employing molybdenum oxide on alumina as a catalyst, maintaining temperature between 524-552°C, and operating at pressures of 1 atm. or less. Conversion per pass ranges from 5-10%. Overall yields from 60-85% based toluene are reported.
2. Input Materials - Basis: 1 kg benzonitrile  
Toluene - 0.89 kg  
Ammonia - 0.16 kg  
MoO<sub>3</sub> catalyst - quantities not given
3. Operating Parameters  
Temperature: 524-552°C (975 - 1025°F)  
Pressure: 101 KPa (1 atm) or less  
Yield: 60-85% based on toluene
4. Utilities - Quantities not given
5. Waste Streams - Off gases contain ammonia, hydrogen cyanide and toluene. Air vent streams from the purification system would contain toluene.
6. EPA Source Classification Code - None



7. Reference

Astle, M.J., Industrial Organic Compounds, Reinhold Publishing Corporation, New York, 1961, p. 227-228.



1. Function - The preferred industrial process in the manufacture of benzoic acid, in the United States, is the air oxidation of toluene.

The reaction is carried out in the liquid phase at 110 - 150°C at pressures of 273 - 490 kPa (2.7 - 5 atm) using a cobalt salt usually the naphthenate as the catalyst. The heat of reaction is controlled by refluxing toluene and water-jacketed cooling. Water of reaction is removed from condensed off gas before the toluene is returned to the reactor heel. Material in the autoclave heel continuously overflows to a stripper where toluene is recycled. The bottoms, which contains the crude benzoic acid, are sent to a crystallizer, or a distillation tower. Yields of relatively pure material of 90% based on toluene are cited.

2. Input Materials - Basis 1 kg benzoic acid.

|                    |                   |
|--------------------|-------------------|
| Toluene            | .83 kg/kg         |
| Air                | 1.71 kg/kg        |
| Cobalt naphthenate | .008 - .024 kg/kg |

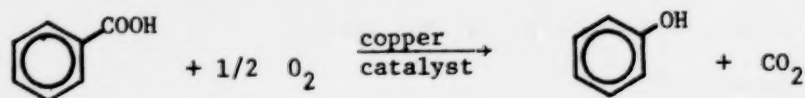
3. Operating Parameters

Temperature: 110 - 150°C (230-302°F)

Pressure: 273 - 490 kPa (2.7 - 5 atm)

Catalyst: 0.1 - 0.3% of toluene

4. Utilities - Based on 100  $\bar{M}$  lb/yr capacity  
Water -  $.545 \text{ m}^3/\text{sec}$  (518,000 gPh)  
Steam -  $5.93 \text{ kg/sec.}$  (47,000 lbs/hr)  
Power 2,320
5. Waste Streams - Air vent stream from the purification contains toluene, some benzaldehyde and some benzyl alcohol. The air vent from the separator (centrifuge) contains toluene vapors. The waste water contains benzoic acid, benzaldehyde and benzyl alcohol.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1967), p. 420-439.  
  
Sittig, M., Organic Chemical Process Encyclopedia, 2nd Edition, Noyes Development Corporation, Park Ridge, New Jersey, 1969, p. 101.  
  
Hedley, W.H. et. al., Potential Pollutants from Petrochemical Processes, Final Report, Contract 68-02-0226, Task 9, MRC-DA, 406, December 1973, p. 111-112.

Phenol (oxidation of Benzoic acid)

1. Function - Benzoic acid is melted in biphenyl, mixed with a small amount of manganese-promoted cupric benzoate and fed to an oxidizer (reactor). A mixture of air and steam is sparged into the reactor, where the benzoic acid is oxidized to phenol.

Purification is accomplished by distillation. Phenol and water are taken off overhead and benzoic acid is taken from the column bottom and returned to the reactor. The bottoms may be extracted first, to recover organics for recycle. The phenol and water are separated by azeotropic distillation.

2. Input Materials

Benzoic acid

Air

Catalyst

3. Operating Parameters

Temperature - 230°C (446°F)

Pressure - 138-172 kPa (1.36-1.7 atm)

Mn-cupric benzoate - not given

4. Utilities - Not given

5. Waste Streams

Centrifuged separator (solid)

Tar -0.10 kg/kg phenol (204 lb/ton)

Phenyl benzoate -0.0015 kg/kg phenol (3.1 lb/ton)

5. Waste Streams (continued)

Acetone -0.0018 kg/kg phenol (3.6 lb/ton)

Manganese benzoate -0.005 kg/kg phenol (10 lb/ton)

Copper benzoate -0.002 kg/kg phenol (4.3 lb/ton)

Separator effluent

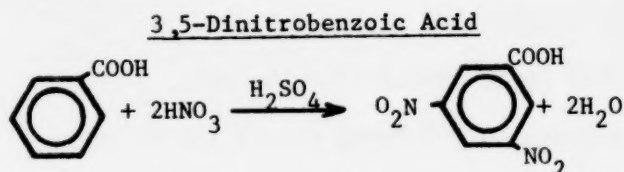
Toluene -0.0011 kg/kg phenol (2.14 lb/ton)

6. EPA Source Classification Code - None

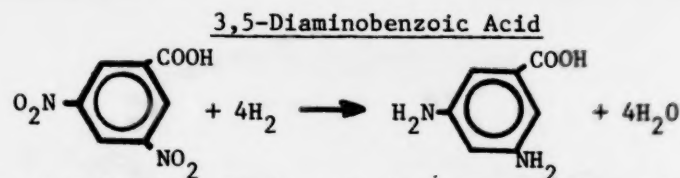
7. References

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th Edition,  
John Wiley & Sons, New York, N.Y., 1975, p. 618-619.

Hedley, W. H., et al., "Potential Pollutants from Petrochemical Processes,"  
Prepared for Environmental Control Systems Laboratory, NERC, Environmental  
Protection Agency, Contract No. 68-02-0226, Task No. 9, 1973, p. 111-112.

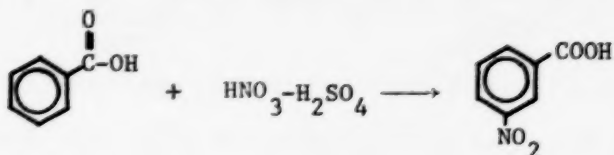


1. Function - 3,5-Dinitrobenzoic acid is primarily manufactured by nitrating benzoic acid with a mixture of fuming nitric and sulfuric acids. The sulfuric acid forms a hydrated molecule and removes the water of reaction. The nitration occurs at elevated temperatures (70-90°C).
2. Input Materials - Basis: 1 kg 3,5-dinitrobenzoic acid  
Benzoic acid - 0.6 kg  
HNO<sub>3</sub> - 0.6 kg (99+% acid)  
H<sub>2</sub>SO<sub>4</sub>
3. Operating Parameters  
Temperature: 70-90°C (158 - 194°F)  
Pressure: atmospheric
4. Utilities  
Quantities not given
5. Waste Streams - Off gas will contain oxides of nitrogen and some sulfur dioxide. Waste water from the purification process contains nitric and sulfuric acids, benzoic acid and some 3,5-dinitrobenzoic and 3-nitrobenzoic acid.
6. EPA Source Classification Code - None
7. References  
Astle, M.J., Industrial Organic Nitrogen Compounds, American Chemical Society Monograph Series, Reinhold Publishing Corporation, New York, 1961, p. 334.



1. Function - 3,5-Diaminobenzoic acid is commercially produced by the catalytic reduction of dinitrobenzoic acid. The process is similar to that used to manufacture m,p-aminobenzoic acids. The reaction occurs in the liquid phase at about 1 atmosphere pressure. The hydrogen is fed in large excess to a slurry of catalyst, dinitrobenzoic acid and water at temperatures greater than 85°C. The product acid is then filtered to remove catalyst and cooled to precipitate the product.
2. Input Materials - Basis: 1 kg diaminobenzoic acid  
Dinitrobenzoic acid - 1.5 kg  
Hydrogen - >0.03 kg  
Catalyst - quantities not given
3. Operating Parameters  
Temperature: 85°C (185°F)  
Pressure: 100KPa (1 atm)  
Catalyst: Pd, Cu, Pt, or Ni
4. Utilities  
Not given
5. Waste Streams - Off-gas from the reactor contains hydrogen. Waste water contain 2,5-dinitrobenzoic acid and 3,5-diaminobenzoic acid.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3, (1964) pp. 435-436.



m-Nitrobenzoic Acid

1. Function - The product of the nitration of benzoic acid is m-nitrobenzoic acid with the principal byproduct being ortho-nitrobenzoic acid. Almost no p-nitrobenzoic acid is formed and the ortho isomer can be minimized by proper selection of the reaction temperature.

The rate of reaction increases with temperature, however the amount of m-isomer decreases with temperature while the amount of ortho isomer increases. The operating temperature must be a compromise between optimum rate of production and purity of product.

The reaction is carried out in sulfuric acid and a maximum in rate of nitration is found at 89-90% sulfuric acid.

2. Input Materials

Benzoic acid

Nitric acid

Sulfuric acid

3. Operating Parameters

Temperature - 25-45°C

Pressure - Atmospheric

Sulfuric acid - 90%

4. Utilities - Not given

5. Waste Streams - Air vent streams contain oxides of nitrogen.

Waste water streams will contain benzoic acid, some m-nitrobenzoic acid.

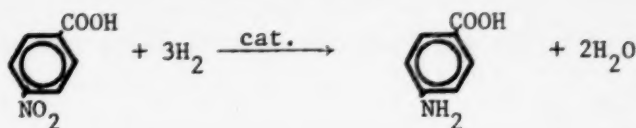
6. EPA Source Classification Code - None

7. References

Hoggett, J. G., Moodie, R. B., Penton, J. R., and Schofield, K.,

Nitration and Aromatic Reactivity, Cambridge University Press,

London, 1971, pp. 16, 18, 151, 160, 178.

m- or p-Aminobenzoic Acids

1. Function - These acids are manufactured chiefly by the reduction of m- or p-nitrobenzoic acids by catalytic hydrogenation or, less frequently, by reduction with tin or iron and HCl. One patent for p-aminobenzoic acid claims an 85% yield when hydrogenating p-nitrobenzoic acid with a Pt or Pd catalyst in water.

A thin slurry of p-nitrobenzoic acid and catalyst in water is agitated at about 800 RPM and held at 85°C. Hydrogen is then introduced until no more absorption is noted and the p-nitrobenzoic acid dissolves as the reaction proceeds. The partial pressure of H<sub>2</sub> is from 200-700 mm Hg in the atmospheric pressure process. The product acid is filtered and cooled to precipitate a 99% product. The mother liquor from precipitation is reused in the next batch.

2. Input materials - Basis: 1 kg of aminobenzoic acid

Nitrobenzoic acid (m-, or p-) - 1.2 kg

H<sub>2</sub> - >0.04 1.2 kg

Catalyst: Pt, Ni, Pd, or Cu - quantities not given

3. Operating parameters

Temperature: 85°C

Pressure: atmospheric

Agitation: 800 RPM

4. Utilities

Quantities not given

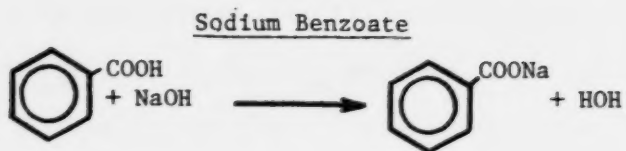
5. Waste streams - The off gas from the hydrogenation reactor contains hydrogen, when iron powder and hydrochloric acid is used hydrogen chloride is present in the off gas. Waste wash water from the centrifuge contains aminobenzoic acid, ferric chloride and HCl. The product contains some m- or p-nitrobenzoic acids.

6. EPA Source Classification Code

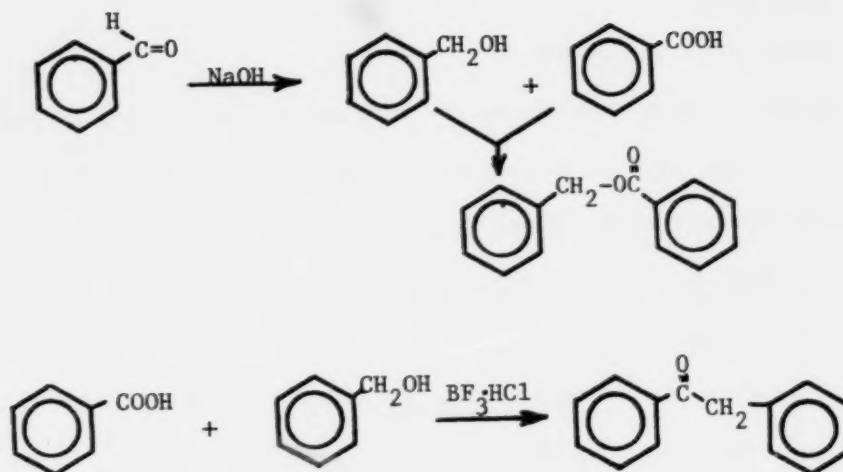
None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publisher, New York, N.Y., Vol. 3 (1967) p. 434-436.



1. Function - Sodium benzoate is generally produced by the addition of benzoic acid to a hot solution of sodium carbonate or sodium hydroxide. The resulting solution is treated with charcoal or, in some cases, potassium permanganate, and is filtered and dried.
2. Input Materials - Basis: 1 kg sodium benzoate  
Benzoic acid - 0.85 kg  
NaOH - >0.3 kg  
Na<sub>2</sub>CO<sub>3</sub> (alternate) - >0.74 kg  
Charcoal - quantity not given  
KMnO<sub>4</sub> - quantity not given
3. Operating Parameters  
Quantities not given
4. Utilities  
Quantities not given
5. Waste Stream - Waste water streams contain sodium hydroxide or sodium carbonate and water use to wash the benzoate product contains NaOH, Na<sub>2</sub>CO<sub>3</sub>, NaHCO<sub>3</sub> and some sodium benzoate. There will be some carbon dioxide in the off gas.
6. EPA Source Classification Code  
None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 3 (1967), p. 433.

Benzyl Benzoate

1. Function - Benzyl benzoate is produced commercially by two routes. The most commonly used commercial process is the Cannizaro reaction in which benzaldehyde, catalyzed by sodium hydroxide, undergoes an oxidation-reduction reaction giving benzyl alcohol and benzoic acid. These compounds undergo an esterification catalyzed by the NaOH to produce benzyl benzoate. The second process involves a direct esterification of benzoic acid and benzyl alcohol catalyzed by a boron trifluoride hydrochloric acid complex. The reactions are carried out at 75-90°C at 1 atm pressure.
2. Input Materials - Basis: 1 kg benzyl benzoate (benzaldehyde route)  
 Benzaldehyde - 2 kg  
 NaOH catalyst/reactant - quantities not given
3. Operating Parameters  
 Temperature: 75-90°C (167-194°F)

Pressure: 100 kPa (1 atm)

Catalyst: NaOH or any strong base

4. Utilities

Quantities not given

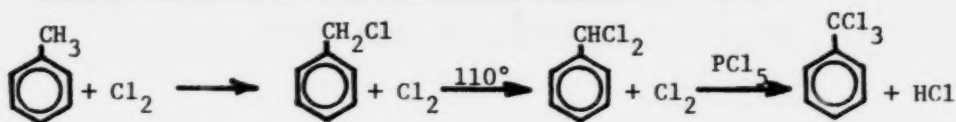
5. Waste Streams - Waste water contains sodium hydroxide, sodium benzoate and some benzaldehyde. No significant quantities of air pollutants would result from this process.

6. EPA Source Classification Code - None

7. References

Shreve, R. N., Chemical Process Industries, McGraw-Hill Book Co., New York, 1967, p. 512.



Benzyl Chloride, Benzoyldichloride, Benzotrichloride

1. Function - The chlorination of toluene to the three products, mono-, di-, and tri-chloromethyl benzene, can be considered as a single process since the extent of chlorination cannot be exactly controlled.

The use of excess toluene will result in a predominance of benzyl chloride. Stopping the reaction when the product density reaches 1.283 will result in a product that is predominantly benzyl chloride and allowing the reaction to continue until the product density reaches 1.38 will yield benzotrichloride.

The reaction must be carried out in glass or polymer lined reactors since iron catalyses nuclear substitution. The temperature is controlled in this exothermic reaction by the reflux of toluene.

2. Input Materials

Toluene

$\text{PCl}_3$  or  $\text{PCl}_5$  (optional)

3. Operating Parameters

Temperature:  $110^\circ \text{C}$

Catalyst:  $\text{PCl}_3$  or  $\text{PCl}_5$  (optional)

Spec. Eqpt.:  $\text{Cl}_2$  resistant container for benzyl - glass  
for benzotrichloride

4. Utilities - Not given
5. Waste streams - HCl is neutralized with a weak base before disposal,  
so chloride salts will be waste.
6. EPA Source Classification Code - None
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 5(1969), p. 281-287.

Austin, G. T., "The Industrially Significant Organic Chemicals-  
Part 1," "Chemical Engineering," January 21, 1974, p. 132.

Benzyl Alcohol

1. Function - Benzyl alcohol is manufactured in the United States exclusively by hydrolysis of benzyl chloride. Sodium hydroxide or sodium carbonate is usually employed but use of the carbonate minimizes formation of by-products such as dibenzyl ether.

A charge consisting of 1349.4 kg (2,975 lb) of water, 1428.8 kg (3,150 lb) benzyl chloride, and 714.4 kg (1,575 lb) sodium carbonate is put into a 3.785 m<sup>3</sup> (1,000 gal) steel jacketed reactor, agitated, and heated to reflux for 24 hours. The reaction is cooled, sodium chloride added to saturation, and the layers allowed to separate. The lower aqueous layer is drained to the sewer while the upper layer of crude benzyl chloride is purified by vacuum distillation.

2. Input Materials

Benzyl chloride - 1.34 kg/kg alcohol  
Sodium carbonate - 0.67 kg/kg alcohol  
Water - 1.27 kg/kg alcohol

3. Operating Parameters

Temperatures: 210°C (410°F)  
Reaction Time: 24 hours  
Equipment: 3.75 m<sup>3</sup> (1,000 gal) steel-jacketed reactor

4. Utilities - Not given
5. Waste Streams - Aqueous layer saturated with sodium chloride and containing sodium carbonate used to be discharged to the sewer but may be disposed of differently now. Waste water may contain traces of benzyl chloride.

6. EPA Source Classification Code - None

7. References

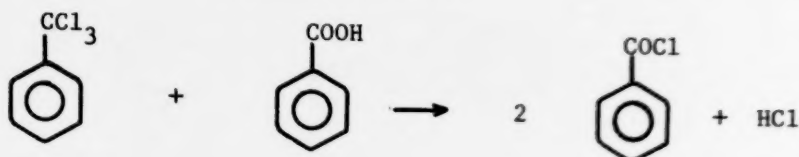
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 3 (1964), p. 443-444.

Benzyl Amine

1. Function - Benzylamine is produced commercially by the ammonolysis of benzyl chloride. The reaction is carried out at elevated temperatures (100–200° C) and pressure (100 kPa–2.76 MPa) and a 4 to 10 X excess of aqueous ammonia. The major product under these conditions of excess ammonia is the primary amine, although some secondary, tertiary and quaternary salts are formed. The water and ammonia are separated and recycled and the amines separated and purified by distillation.
2. Input Materials  
Benzyl chloride  
65% aqueous ammonia
3. Operating Parameters  
Temperature: 150–200° C (302–392°F)  
Pressure: 100 kPa–2.76 MPa (1–27 atm)
4. Utilities - Not given
5. Waste streams - by-product secondary and tertiary amines quaternary salts are formed. Ammonium chloride sent to other processes.
6. EPA Source Classification Code - None
7. References  
Astle, M. J., Industrial Organic Nitrogen Compounds, Reinhold Publishing Corp., New York, N.Y., 1961, p. 6–8.

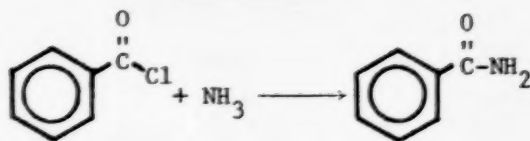
7. References (continued)

Shreve, R. N., Chemical Process Industries, McGraw Hill Book Company, New York, N.Y., 1967, p. 815-816.

Benzoyl Chloride

1. Function - Benzotrichloride and catalyst (zinc chloride impregnated on pumice) are run into a glass-lined steel reactor which has previously been half filled with molten benzoic acid. A glass-coated agitator is used to stirr the mixture and tank temperature is maintained at 122-130°C for about eight hours. A Karbate (impregnated carbon) condenser removes the hydrochloric acid formed in the reaction. The benzoyl chloride is purified by distillation.
2. Input Materials  
Benzotrichloride  
Benzoic acid
3. Operating Parameters  
Temperature: 122-130°C (252-266°F)  
Pressure: 101 kPa (1 atm)  
Catalyst: zinc chloride on pumice
4. Utilities - Not given
5. Waste Streams - Waste waters may contain traces of benzoic acid, benzotrichloride, and zinc chloride.
6. EPA Source Classification Code - None
7. Kirk-Othemer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 3 (1964), p. 424.

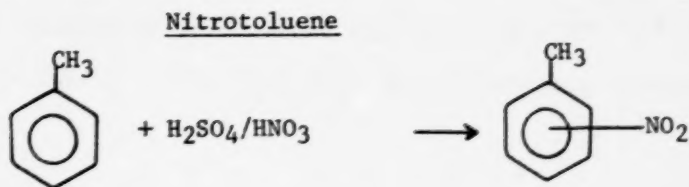


Benzamide

1. Function - Benzamide is produced by the acylation of ammonia with benzoyl chloride. The reaction may be carried out under anhydrous conditions by passing anhydrous ammonia into a solution of benzoyl chloride in an inert solvent such as diethyl ether. In a commercial operation it is more usual to add the benzoyl chloride to a cold (0°C), concentrated aqueous solution of ammonia from which the benzamide precipitates. The crude benzamide is washed with water and purified by recrystallization.
2. Input Materials  
Benzoyl chloride  
Ammonia (anhydrous or concentrated aqueous solution)
3. Operating Parameters  
Temperature - 0°C (32°F)  
Pressure - 101 kPa (1 atm)
4. Utilities - Not given
5. Waste Streams - Air streams may contain ammonia and some hydrogen chloride. Waste water from product recovery and purification contains ammonia, HCl, NH<sub>4</sub>Cl and benzoic acid.
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 69-71.



1. Function - Nitrotoluenes are manufactured by nitration of toluene by a nitrating agent usually consisting of a mixture of sulfuric and nitric acid and recycled fortified acid. The ratio of  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$  and  $\text{H}_2\text{O}$  as well as the temperature and rate of agitation has to be controlled to ensure high yield, favorable ratio of desired isomer, and to minimize dangerous side reactions. Nitration is done at relatively low temperatures ( $\leq 40^\circ\text{C}$ ). The crude product is washed with water, alkali, and water. The isomeric nitrotoluenes are then separated from toluene and other organics by steam distillation and subsequently dried. Separation of the o-, m-, and p-isomers is done by a series of vacuum distillations.
2. Input Materials - basis: 1000 kg yield of nitrotoluene  
Toluene - 690 kg  
Nitric acid - 450 kg  
Sulfuric acid - 810 kg  
Water - 240 kg  
10% NaOH solution - 22 kg
3. Operating Parameters  
Temperature:  $25^\circ\text{C}$  [initially] ( $77^\circ\text{F}$ )  
 $35\text{--}40^\circ\text{C}$  [final] ( $95\text{--}104^\circ\text{F}$ )

Equipment: Toluene nitration is normally carried out in cast-iron or stainless-steel nitrators sized for 3,000 gal batches of toluene.

4. Utilities - None given

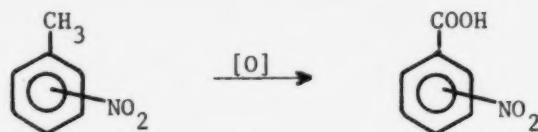
5. Waste Streams - Heavy tar residues from final fractionation stage are disposed of and would contain a complex mixture of organic by-products in the amount of approximately 40 kg/1000 kg nitrotoluene. Waste waters may contain also alkali used in washings, spent acid, and soluble organic by-products.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 13 (1967), p. 844-848.

Albright, L.F. and Hanson, C., "Industrial and Laboratory Nitrations," ACS Symposium Series 22, 1976, p. 190-218.

Nitrobenzoic Acids

1. Function - m-, and p-Nitrotoluene may be oxidized with chromic acid to yield the corresponding m-, and p-nitrobenzoic acids. o-Nitrotoluene is not affected by chromic acid. o-Nitrotoluene is oxidized by potassium permanganate to give o-nitrobenzoic acid.

2. Input Materials

Nitrotoluene

Potassium permanganate (to oxidize o-nitrotoluene or p-nitrotoluene)

Chromic acid (to oxidize m- and p-nitrotoluene)

3. Operating Parameters

Temperature: 25-50°C (77-122°F)

Pressure: 101 kPa (1 atm)

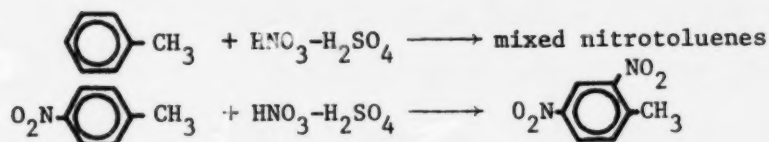
4. Utilities - Not given

5. Waste Streams - Neutralization of reaction waste liquors would give wastewater streams containing salts of the acid or alkali used.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N. Y., Vol. 13 (1967), p. 848-850.

Dinitrotoluene (nitration of toluene)

1. Function - The reaction of nitric acid and toluene to produce dinitrotoluene can be thought of as a two stage reaction. The first stage being the mononitration of toluene. The nitrating agent is the acid mixture 48% sulfuric, 18% nitric, 14% nitrosylsulfuric, 12% water and 8% nitroorganics, which is typical of the fortified spent acid from the dinitration stage. The temperature is initially 25° C raised to 40° C to complete the reaction. The reactor must be vigorously agitated since the toluene is not very soluble in the mixed acids. A typical product mix is 62% ortho, 33% para and 3% meta. The mixture may be separated or used as is in the second nitration step.

The acid mixture used in the second stage contains, for a typical mixture, 50% sulfuric, 20% nitric, 12% nitrosylsulfuric 6% water and 12% nitroorganics. The temperature must be increased to 55 to 85° C at 1 atm pressure. Nitration of the pure p-isomer yields 2,4-dinitrotoluene with no significant amounts of by-product. Nitration of the unresolved product of the mononitration yields an 80-20 mixture of 2,4 and 2,6-dinitrotoluene, respectively. The product mixture may be separated into the pure isomers by crystallization or used directly for the manufacture of toluenediisocyanate.

2. Input Materials

Toluene: 506.25 kg/Mg of product  
Nitric Acid: 721.25 kg/Mg of product  
Sulfuric Acid: 1311 kg/Mg of product  
Nitrosyl sulfuric acid: 262 kg/Mg of product

3. Operating Parameters

Temperature: mononitration 25-40° C (77-104°F)  
dinitration 50-85° C (122-185°F)  
Pressure: 100 KPa

4. Utilities - Not available

5. Waste Streams

Decantors (water) - Wastewater from the decantors, containing small amounts of nitrated toluene, is discarded and may end up in sewer lines.

Absorber (air) - Reactor vents go to the absorber to oxidize the NO to NO<sub>2</sub> which is absorbed in water to produce nitric acid. Vent from absorber discharges air and unabsorbed oxides of nitrogen.

Washer vents (air) - Air saturated with water and some nitrated toluenes will be discharged from the washer vent.

6. EPA Source Classification Code - None

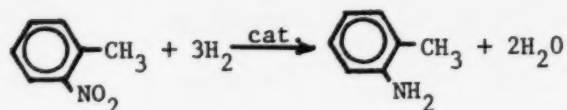
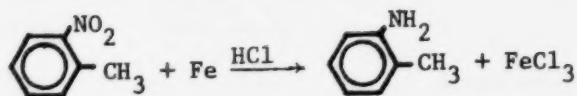
7. References

Austin, G. T., "Industrially Significant Organic Chemicals,"  
"Chemical Engineering," April 15, 1974.

Sittig, M., "Pollution Control in the Organic Chemical Industry,"  
Noyes Data Corporation, Park Ridge, N.J., 1974, p. 126-27.

Brownstein, A. M., "U.S. Petrochemicals - Technologies, Markets  
and Economics," The Petroleum Publishing Company, Tulsa, Oklahoma, 1972.



Toluidines

1. Function - The toluidines are made from the nitrotoluenes by reduction. The process most commonly used is the metal-acid process, the most widely utilized combination being iron and hydrochloric acid. Nitrotoluene, powdered iron, and a small amount of water are mixed in a reaction vessel. Hydrochloric acid is added at a rate such that the heat of reaction will maintain a brisk rate of reaction. The converted toluidine is steam distilled, from the reactor, separated, and purified by distillation. Approximately 3.1% of the toluidine remains in the aqueous layer most of which may be recovered by solvent extraction.

Catalytic hydrogenation has been replacing the iron-acid method in recent years yielding a purer product at lower cost. The reduction is done in the vapor phase, passing hydrogen and the nitrotoluene vapor through a fluidized bed of copper clad silica gel.

2. Input Materials

|                      |                                 |
|----------------------|---------------------------------|
| Iron reduction:      | Nitrotoluene                    |
|                      | Hydrochloric acid - iron powder |
| Catalytic reduction: | Nitrotoluene                    |
|                      | Hydrogen                        |

3. Operating Parameters

|                      |              |                        |
|----------------------|--------------|------------------------|
| Iron reduction:      | Temperature: | 100° C (212°F)         |
|                      | Pressure:    | 100 kPa (1 atm)        |
| Catalytic reduction: | Temperature: | 250-300° C (482-572°F) |
|                      | Pressure:    | 238 kPa (2.5 atm)      |
|                      | Catalyst:    | Copper on silica       |

4. Utilities - Not available

5. Waste streams - the major waste water stream is from the steam stripper for the aqueous layer and contains approximately 0.2% toluidine as well as some HCl. Some toluidine hydrochloride is lost in the waste water from the reactor after steam distillation. Air streams contain hydrogen chloride and some particulates.

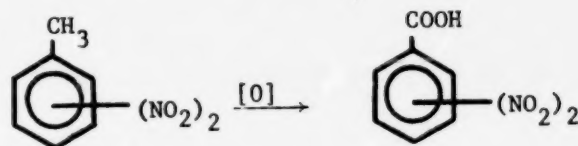
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 2 (1963), p. 79, 421.

Ibid., Vol. 13 (1967) p. 852.

Kent, J. A., Riegel's Handbook of Industrial Chemistry, 7th Edition, Van Nostrand-Reinhold Company, New York, N.Y., 1974.

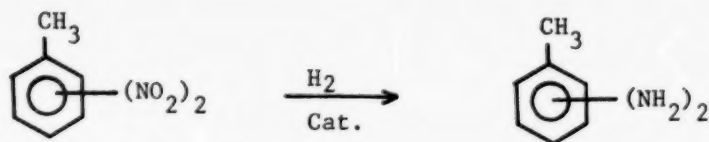
Dinitrobenzoic Acids

1. Function - 2,4-Dinitrotoluene and 2,6-dinitrotoluene are obtained by the dinitration of toluene by conventional nitrating process. The corresponding benzoic acids may be obtained by nitrating in the presence of  $\text{CrO}_3$  or  $\text{Na}_2\text{Cr}_2\text{O}_7$ .
2. Input Materials  
Toluene  
 $\text{Na}_2\text{Cr}_2\text{O}_7$   
 $\text{HNO}_3\text{-H}_2\text{SO}_4$
3. Operating Parameters  
Temperature:  $0^\circ\text{C}$  ( $32^\circ\text{F}$ )  
Pressure: 101 kPa (1 atm)  
Time: 1 to 2 hr
4. Utilities - not given
5. Waste Streams - Typical nitration waste streams ( $\text{NO}_x$ , spent acid) should be present as well as some chromium salts in the sludge.
6. EPA Source Classification Code - None
7. References  
Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 13 (1967), p. 851.

7. References (continued)

Tadeuz, Urbanski, et al., Biul. Wojskowej Akad. Tech. 9, No. 97,  
73-83 (1960).

Adolph, E. et al., Tetrahedron, 19(6), 801-7 (1963).

2,4- and 2,6-Diaminotoluenes

1. Function - The usual industrial dinitration of toluene gives a mixture of 2,4- and 2,6-dinitrotoluenes in a 80:20 ratio. A conventional liquid phase hydrogenation yields the 2,4- and 2,6-diaminotoluenes. The mixture of the diamines is used to manufacture the corresponding diisocyanates used in urethane manufacture.
2. Input Materials  
Dinitrotoluenes - 1.57 kg/kg Diaminotoluenes  
Hydrogen - 0.106 kg/kg Diaminotoluenes
3. Operating Parameters

|               |                      |
|---------------|----------------------|
| Temperature:  | 90-190°C (194-374°F) |
| Pressure:     | 606 kPa (6 atm)      |
| Catalyst:     | palladium on carbon  |
| Phase:        | liquid               |
| Reactor type: | jacketed kettle      |
| Solvent:      | water                |
4. Utilities - Basis: 9.41 Gg (20.75 M lb)/yr. capacity (based on DuPont patents)

|                     |                                          |
|---------------------|------------------------------------------|
| Cooling water       | - 568 m <sup>3</sup> (150,000 gal.)/hour |
| Demineralized water | - 681 m <sup>3</sup> (180,000 gal.)/hour |
| Steam               | - 5.94 Mg (13,100 lb)/hour               |
| Fuel                | - 5.9 GJ (5.6 M BTU)/hour                |
| Electricity         | - 634 MJ (176 kWh)/hour                  |

5. Waste Streams

Recovery section (water), Toluidine - 11 gm/kg Diaminotoluenes

Purification section (water), Toluenediamine - 9.8 gm/kg

Diaminotoluenes

6. EPA Source Classification Code - None

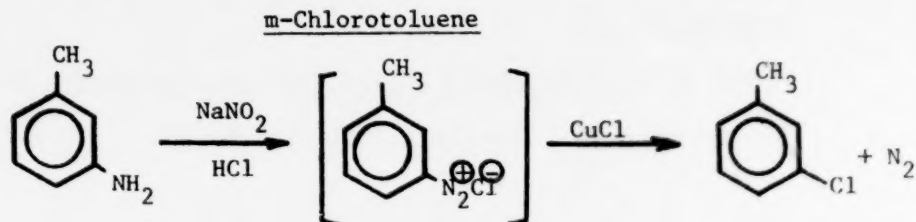
7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, Interscience Publishers, New York, N.Y., 2nd Edition, Vol. 20 (1969), p. 562.

Yen, Y. C., Isocyanates - Part I, Report No. 1-A, Stanford Research Institute, Menlo Park, California, June 1968.

Sittig, M., Organic Chemical Process Encyclopedia - 1969, Noyes Development Corp., Park Ridge, N.J., 1969.

Albright, Lyle F., and Hanson, Carl, "Industrial and Laboratory Nitrations", ACS Symposium Series 22, 1976, p. 314.



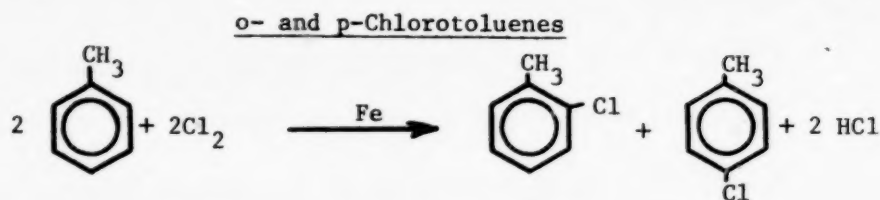
1. Function - m-Chlorotoluene is made by the replacement of the amino group of m-toluidine with a chlorine by formation of a diazonium salt and the reaction of the diazonium salt with cuprous chloride. The reaction is carried out by dissolving the m-toluidine in a 2.5X excess of aqueous hydrochloric acid containing the cuprous chloride. A solution of sodium nitrite is added giving nitrous acid in situ. The product is insoluble in water and separates as a nonaqueous layer. Purification is accomplished by distillation. Urea may be added to remove excess nitrous acid.
2. Input Materials - Basis: 1 kg m-chlorotoluene  
meta-Toluidine - 0.85 kg  
Hydrochloric acid (2.5X excess)  
Sodium nitrite  
Cuprous chloride
3. Operating Parameters  
Temperature: 0.5°C  
Pressure: 100 kPa (1 atm)
4. Utilities - Not available
5. Waste Streams - Air vent streams contain hydrogen chloride, nitrogen, nitric oxide and nitrogen dioxide. Waste water streams contain hydrochloric acid, m-toluidine hydrochloride, some copper salts and small quantities of m-chlorotoluene.



6. EPA Source Classification Code - None

7. References

Astle, M. J., Industrial Organic Nitrogen Compounds, Reinhold  
Publishing Corp., New York, 1961, p. 198-200.



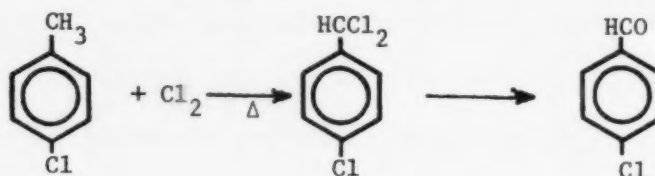
1. Function - Ortho- and para-chlorotoluenes are prepared by direct catalytic chlorination of toluene. The reaction is carried out in a liquid phase reactor at a temperature of 110-130°C and 1 atmosphere pressure, in the presence of iron powder to facilitate ring chlorination. By-products of the reaction are dichlorotoluenes and higher chlorinated derivatives. These are separated from the mono-chloro products by distillation. The o- and p- isomers are separated by fractional crystallization.
2. Input Materials - Basis: 1 Kg chlorotoluene  
 Toluene - .91 Kg/Kg  
 Chlorine - .70 Kg/Kg  
 Iron Turnings  
 Sodium hydroxide (10% aqueous to neutralize chlorinated toluenes)
3. Operating Parameters  
 Temperature - 110-130°C  
 Pressure - 100 kPa (1 atm)
4. Utilities - Not available
5. Waste Streams - Air vent streams contain chlorine, hydrogen chloride and some toluene. Vent on absorber emits chlorine, some toluene. Water from decanter contains sodium hydroxide, sodium chloride some dichlorotoluenes. Vent stream from stripping column contains toluene.

6. EPA Source Classification Code - None

7. References

Faith, W.L. et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N.Y., 1965, p. 261-263.

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corporation, Park Ridge, N.J., 1974, p. 103.

p-Chlorobenzaldehyde

1. Function - p-Chlorobenzaldehyde is produced by hydrolyzing p-chlorobenzalchloride, a side chain chlorination product of p-chlorotoluene. p-Chlorotoluene is chlorinated at 160°C and 1 atmosphere pressure in a glass lined reactor, to prevent metal catalyzed ring chlorination. The extent of chlorination is estimated by measuring the density of the reaction product. This method of control results in by-product of chlorobenzylchloride and chlorobenzotrichloride.

The crude chlorobenzal chloride is hydrolyzed by boiling water yielding chlorobenzaldehyde and by-products of chlorobenzylalcohol, and chlorobenzoic acid.

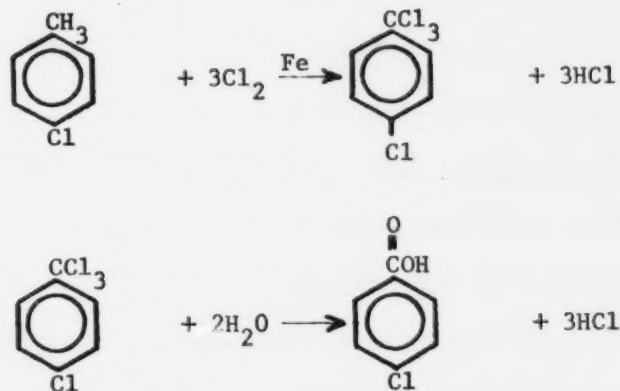
2. Input Materials - Based on 1 Kg chlorobenzaldehyde  
Chlorotoluene - 0.9 Kg  
Chlorine - 70.5 Kg  
Water - 70.13 Kg
3. Operating Parameters  
Temperature - 160°C  
Pressure - 100 kPa (1 atm)
4. Utilities - Not given

5. Waste Streams - Vent on gas absorber emits hydrogen chloride and chlorine. Waste water streams may contain hydrochloric acid, benzoic acid, chlorobenzylalcohol and some chlorobenzaldehyde. Because the heat of reaction for the chlorination is controlled by the reflux of chlorotoluene some chlorotoluene vapors may be emitted.

6. EPA Source Classification Code - None

7. References

Faith, W.L. et al., Industrial Chemicals, 3rd Edition, John Wiley and Sons, New York, N.Y., 1965, p. 120,121.

Chlorobenzoic Acids (o- and p-)

1. Function - Chlorobenzoic acids may be prepared by a variety of methods based on well-known reactions. The ortho and para acids can be made from o-chlorotoluene and p-chlorotoluene, respectively, by chlorinating the substituted toluene in the side chain to the chloro-benzotrichloride stage (indicated by the density of the reaction product), and then hydrolyzing.

Mixed o, p-acids are manufactured by reacting mixtures of o, p-chlorotoluenes. The meta acid can be made by direct chlorination of benzoic acid.

2. Input materials - Basis: 1 kg p-chlorobenzoic acid  
p-chlorotoluene - 0.81 kg  
Chlorine - >1.3 kg

Water - >0.23 kg

Catalyst - quantity not given

3. Operating parameters

Temperatures: 160°C chlorination; 100°C hydrolysis

Pressure: 100 kPa (1 atm)

Catalyst: zinc chloride

4. Utilities - none available

5. Waste Streams - Hydrogen chloride is emitted from the vent in the gas absorber, possibly some chlorine is also emitted. Waste water streams may contain sodium hydroxide, sodium chloride, sodium chlorobenzoate, zinc chloride and by-products of chlorobenzaldehyde and chlorobenzylalcohol depending upon the purity of the chlorobenzotrichloride hydrolyzed.

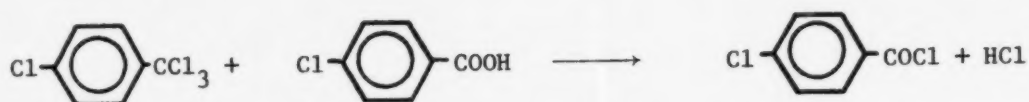
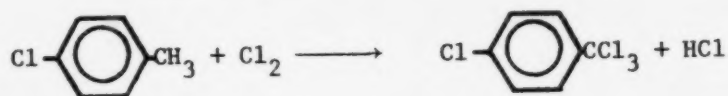
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, Vol. 3 (1967), pp. 436-437.

Faith, W. L., D. B. Keyes and R. L. Clark, Industrial Chemicals, 3rd Edition, John Wiley and Sons Inc., New York, 1965, pp. 141-142.

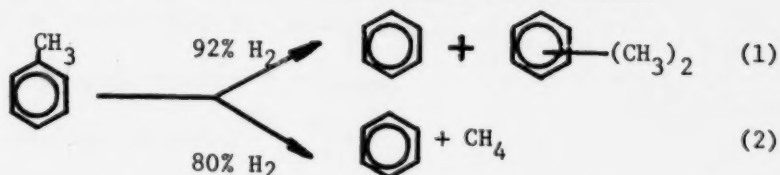


Chlorobenzoyl Chlorides (o- and p-)

1. Function - Chlorobenzoyl chloride is made by the reaction of chlorobenzoic acid and chlorobenzotrichloride. This may be operated as part of the process for producing benzoic acid. The product, benzoic acid, is mixed with unhydrolyzed benzoic acid precursor, chlorobenzotrichloride and heated.
2. Input Materials  
Chlorobenzoic acid  
Chlorobenzotrichloride
3. Operating Parameters  
Temperature: 150-250°C (302-482°F)  
Pressure: 100 kPa (1 atm)
4. Utilities - Not available
5. Waste Streams - Vent from gas absorber emits some hydrogen chloride and chlorine. Bottoms from the distillation column contain unreacted chlorobenzoic acid and chlorobenzochloride.
6. EPA Source Classification Code - None
7. References  
Staff, Chemical Origins and Markets, Chemical Information Services, Stanford Research Institute, Menlo Park, California (1967), p. 21.

7. References (continued)

Hahn, A. V., The Petrochemical Industry, McGraw-Hill Book Co.,  
New York, (1970), p. 518.

Benzene and Xylenes (disproportionation; hydrodealkylation)

1. Function - Benzene and xylene are formed by the disproportionation of toluene. Benzene can be produced by the hydrodealkylation (2) of toluene. Both of these processes are becoming increasingly important because of the rising demand for benzene in industry. Petroleum stocks have been the principal sources of benzene in recent times; but the ratio of benzene/toluene/xylenes produced by the catalytic reformer processes is almost exactly opposite to the demand for these products. It was necessary therefore to develop process to produce benzene from toluene and xylene. Both catalytic and thermal processes are employed.

There are four major processes used to convert alkyl benzenes to benzene: Howdry (a fixed bed catalytic process), Hydeal (catalytic dealkylation), Hydrodealkylation, and the Thermal Hydrodealkylation (a non-catalytic, elevated temperature and pressure).

2. Input Materials

Hydrogen

Toluene

$\text{C}_8$  Aromatics

Alkylbenzenes

3. Operating Parameters

Detol:            temperature - 538-649° C (1000-1200° F)  
                  pressure - 3.5-8.3 MPa (34-82 atm)  
                  catalyst - poison resistant, non-noble metal  
                                         compound pellets

Hydeal:           Not given

Hydrodealkylation: temperature - 593-760° C (110-1400° F)  
                                         pressure - 3.5-7.0 MPa (34-68 atm)

THD:               Not given

4. Utilities - disproportionation of toluene

Electric power - 263 MJ (73 kWh)

Steam - 1.2 Mg (1.5 short tons)

Cooling water ( $\Delta T$  10° C) - 2.1 Mg (3.6 short tons)

Fuel - 2.0 GJ ( $0.7 \times 10^6$  kcal)

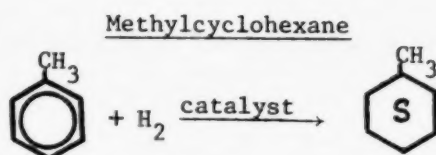
5. Waste streams - C<sub>9</sub> aromatic hydrocarbon plus diphenyl and higher condensed aromatics as bottoms. Lighter paraffins and olefins as overhead or raffinate. By-product formation 29 kg (64 lb)/1000 kg (metric ton) product.

6. EPA Source Classification Code - None

7. References

Anon., "Detol," "Hydeal," "Hydrodealkylation," and "Thermal Hydrodealkylation," Pet. Refiner, 40(11), 236, 251, 252, 298 (1961).

Mager, E. M., "Aromatics Production," U.S. Petrochemicals, Technologies, Markets, and Economics, Brownstein, A. M., Ed., The Petroleum Publishing Company, Tulsa, Okla., 1972, pp. 123-125.

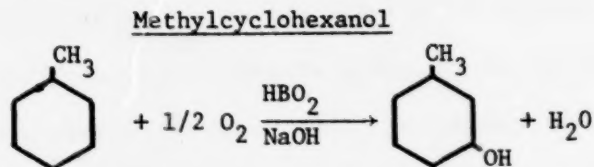


1. Function - Methylcyclohexane is produced commercially by the catalytic reduction of toluene. Since the reaction is catalyzed by Raney nickel, a catalyst which is severely poisoned by sulfur compounds, it is necessary to desulfurize the toluene or to use sulfur-free toluene as the starting material. The reaction is carried out in the liquid phase at 220° C and pressures of 25-34 atm. It is usually carried out in a series of reactors to reduce the amount of recycle, cooling methylcyclohexane in order to avoid excessive catalyst bed temperatures which can lead to isomerization.
2. Input Materials  
Toluene  
Hydrogen
3. Operating Parameters  
Temperature: 220° C to 270° C (428-518° F); average conditions 220° C (428° F)  
Pressure: 2.5-3.6 MPa (25-34 atm)  
Catalyst: Supported nickel or platinum catalyst
4. Utilities - Not given
5. Waste Streams - rearrangement by-products such as dimethylcyclopentanes, ethylcyclopentanes, and paraffinic residues as still bottoms or overheads.

6. EPA Source Classification Code - None

7. Reference

Hydrocarbon Processing and Petroleum Refiner 40(11), 234, 1961.



1. Function - Large scale manufacture of methylcyclohexanol employs the oxidation of methylcyclohexane. The process can start by the direct oxidation of methylcyclohexane. The oxidation is most preferably carried out in the presence of metaboric acid, although other special boron compounds can be used. Oxygen reacts with methylcyclohexane to form methylcyclohexyl hydroperoxide, which on reaction with metaboric acid is believed to form a peroxyborate. This peroxyborate is thought to react subsequently to make cyclohexyl borate esters. Caustic may be used in neutralization of product. The water of reaction must be maintained at very low levels or product yield is decreased. The process for producing methylcyclohexanol is similar, if not identical, in some cases to that used to produce cyclohexanol. Methylcyclohexanol is also produced by the hydrogenation of o, p-cresols.
2. Input Materials - Basis: 1 kg methylcyclohexanol  
Methylcyclohexane - 0.98 kg  
Oxygen - 0.16 kg  
Metaboric acid - quantity not given  
Caustic - quantity not given
3. Operating Parameters  
Temperature: 185 - 200°C (365-392°F)  
Pressure: 2040 - 4800 (20 - 47 atm)  
Catalyst: boric acid or none (5% of Hydrocarbon)



4. Utilities - Quantities not given
5. Waste Streams - The principal source of air pollution occurs during the removal of the water of reaction by azeotropic distillation of cyclohexane-water. Boric acid is recovered and cyclohexane is recycled. Some cyclohexane may be present in the air vent streams. Spent caustic from hydrolysis of borate esters as well as small quantities of cyclohexanol will be present in the waste process water.

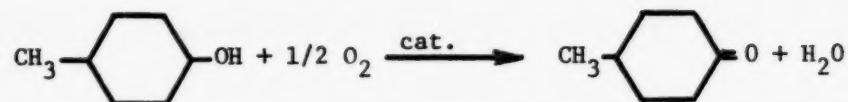
6. EPA Source Classification Code - None

7. References

Considine, D.M., Chemical and Process Technology, McGraw-Hill Book Company, New York, 1974, pp. 337-338.

Sittig, M., Organic Chemical Process Encyclopedia 1969, 2nd Edition, Noyes Development Corporation, Park Ridge, New Jersey, 1969, p. 203.

Waddams, A.L., Chemicals from Petroleum, 3rd Edition, John Murray, London, 1973, p. 240-241.

Methylcyclohexanone

1. Function - Commercial processes employ air oxidation of methylcyclohexanol to produce methylcyclohexanone.

The reaction occurs in a fixed bed multitubular reactor in the vapor phase. A silver or copper catalyst is used.

2. Input Materials - Basis - 1 kg methylcyclohexanone

Methylcyclohexanol - 1 kg

Air - >0.14 kg

Catalyst - quantity not given

3. Operating Parameters

Temperature: ~630°C (1166°F)

Pressure: atmospheric

Catalyst: silver or copper

4. Utilities - Not given

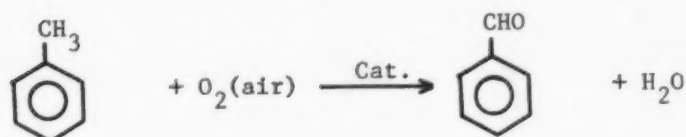
5. Waste Streams - No specific information was found. Gaseous emissions would include methylcyclohexanol, methylcyclohexanone, and a host of by-products from side reactions depending on catalyst efficiency. The condensed water which is separated and disposed of may contain methylcyclohexanone as well as other organic impurities from the high temperature oxidation.

6. EPA Source Classification Code - None

7. References

Sittig, M., Organic Chemical Process Encyclopedia, 2nd Edition,  
Noyes Development Corporation, Park Ridge, N.J., (1969), p. 433.

U.S. Patent 2,930,679 (March 29, 1960).

Benzaldehyde

1. Function - Toluene can be directly oxidized in the vapor phase to benzaldehyde by using a mixture of air and toluene vapors (14:1 weight ratios) in the presence of a 93% uranium oxide, 7% molybdenum oxide catalyst. Small amounts of CuO are added to minimize oxidation to maleic anhydride.

Direct oxidation of toluene is not the only process used. Some quantities are manufactured by hydrolyzing benzal chloride.

2. Input Materials - Basis: 1 kg Benzaldehyde (direct oxidation route)

Toluene - 2.2 kg

Air - 30.2 kg

Catalyst - quantity not given

3. Operating Parameters

Temperature: 500°C (932°F)

Pressure: 101 kPa (1 atm)

Catalyst: molybdenum oxide - 7%/uranium oxide - 93% with cuprous oxide

4. Utilities - quantities not given

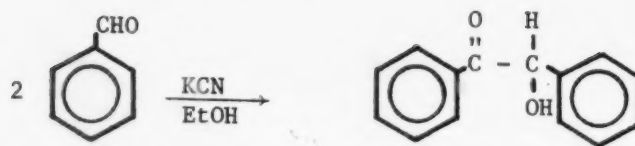
5. Waste Streams - By-products such as benzoic acid, maleic anhydride, CO, CO<sub>2</sub>, anthraquinone, and high boiling oils; scrubber wastes.

6. EPA Source Classification Code - None

7. References

Faith, W. L., et al., Industrial Chemicals, John Wiley and Sons, Inc., New York, N.Y., 3rd Edition, 1965, p. 120-124.

Hahn, A. V., The Petrochemical Industry: Market and Economics, McGraw-Hill Book Co., New York, N.Y., 1970, p. 519-518.

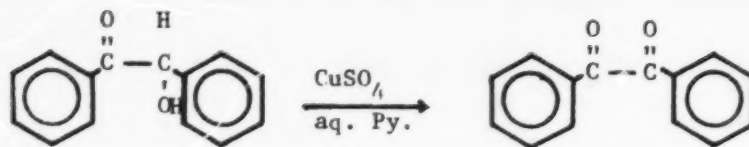
Benzoin

1. Function - Benzoin is manufactured by the reductive condensation of benzaldehyde in an alkaline cyanide solution. The reaction occurs in the liquid phase in alcohol (commonly ethyl alcohol) which will solubilize benzaldehyde, cyanide, and benzoin. The reaction is carried out at reflux conditions.
2. Input Materials - Basis - 1 kg benzoin  
Benzaldehyde - 1 kg  
Potassium cyanide catalyst - quantity unknown
3. Operating Parameters  
Temperature - 80°C (reflux temperature of ethyl alcohol) (176°F)  
Pressure - 101 kPa (1 atm)  
Time for reaction - 1-3 hours  
Catalyst - potassium cyanide
4. Utilities - Not given
5. Waste Streams - The reflux of ethyl alcohol to control the heat of reaction may cause the presence of ethanol and HCN in the vent streams. Potassium cyanide, ethanol, and benzaldehyde will be found in the waste water streams.
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 3 (1967), p. 365.

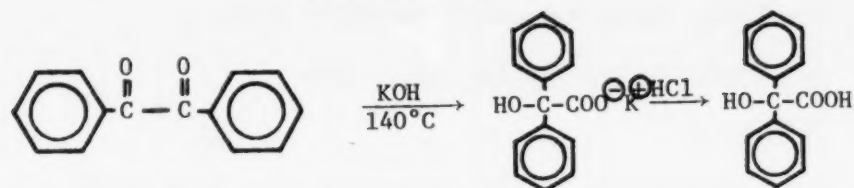


Benzil

1. Function - The  $\alpha$ -diketone benzil is obtained in high yield by oxidation of benzoin with nitric acid in acetic acid solution or with copper sulfate in aqueous pyridine. Reaction occurs at reflux conditions.
2. Input Materials - Basis: 1 kg benzil  
Benzoin - 1 kg  
 $\text{CuSO}_4$ , pyridine - quantities not given  
Water or  $\text{HNO}_3$   
Acetic acid
3. Operating Parameters  
Temperature -  $230^\circ\text{C}$  (reflux condition) ( $446^\circ\text{F}$ )  
Pressure - 101 kPa (1 atm)  
Catalyst -  $\text{CuSO}_4$
4. Utilities - Not given
5. Waste Streams - Pyridine, acetic acid,  $\text{HNO}_3$ , as well as products and reactants may be present in wastewater. The reaction occurs at reflux. Thus, pyridine, acetic acid, and nitric acid may be present in vent gas.
6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishing Co., New York, N.Y., Vol. 12 (1967), p. 146-147.  
U. S. Pat. 2,377,749 (June 5, 1945).

Benzilic Acid

1. Function - Benzilic acid is produced from benzil by a base catalyzed rearrangement. The reaction is run in water at slightly elevated pressure and a temperature of 140°C (melting point of benzil = 137°C). Alternately a sodium hydroxide-sodium bromate catalyst mixture is employed at a temperature of 85-90°C and ambient pressure.

At the conclusion of the reaction (4-5 hours) the sodium salt of benzilic acid is neutralized with hydrochloric acid and crystallized from the solution as it cools to room temperature. The product separated after washing, is of sufficient purity for use in most applications. Crystallization from benzene can be employed to produce a benzilic acid of superior purity.

2. Input Materials

Potassium hydroxide - 0.2 kg

Benzil - 1 kg

Hydrochloric acid - 0.16 kg

3. Operating Parameters

Temperature - 140°C

Pressure - Not given

4. Utilities - Not given

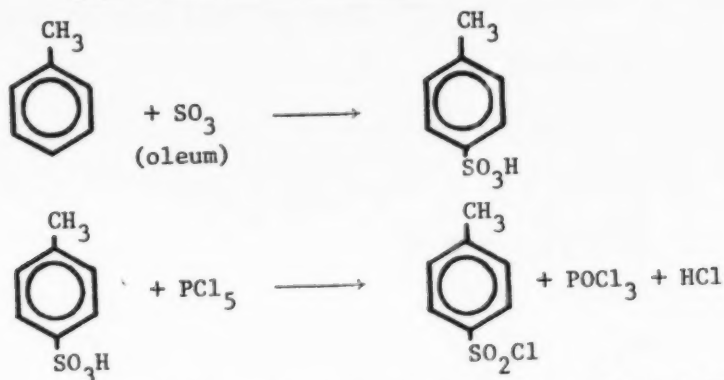
5. Waste Streams - Air vent streams may contain some hydrogen chloride. Waste water contain potassium chloride, potassium hydroxide, sodium benzilate, minor amounts of benzilic acid.

6. EPA Source Classification Code - None

7. References

Doering and Urgan, J. Am. Chem. Soc., 78, 5938 (1956).

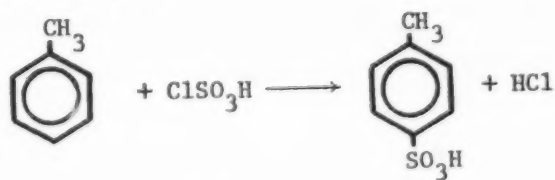
Ballard, D. A., and Dehn, W. M., Org. Syn. Coll., Vol. 1, 89 (1941).

p-Toluenesulfonyl Chloride

1. Function - p-Toluenesulfonyl chloride is produced, industrially from toluene, oleum and phosphorus pentachloride. The first stage produces p-toluenesulfonic acid. Toluene and oleum are combined to give o- and p-toluene sulfonic acid. The p-isomer is favored at higher temperatures, however the o-isomer can be isomerized to the p- by heating to 140°C. The solution is neutralized with  $\text{Ba(OH)}_2$  or  $\text{BaCO}_3$ , precipitating  $\text{BaSO}_4$  and leaving the sulfonic acids in solution from which they are recovered by crystallization.

The sulfonic acids are converted to the sulfonyl chlorides through the action of phosphorous pentachloride. The use of  $\text{PCl}_5$  instead of  $\text{Cl}_2$  obviates the need for non-ferrous reaction vessels and reaction in the absence of light.

An alternate route to p-toluenesulfonyl chloride is also a two step process using chlorosulfonic acid as both the sulfonating and the chlorinating reagent.





An excess of chlorosulfonic acid is used to drive the reaction to completion.

2. Input Materials - Basis - 1 kg p-toluenesulfonyl chloride ( $\text{SO}_3$ ,  $\text{PCl}_5$  route)

Toluene - 0.48 kg

Oleum - 2.1 kg

$\text{PCl}_5$  - .31 kg

3. Operating Parameters

Temperature: sulfonation - 30-40°C (86-104°F)

chlorination - 80°C (176°F)

Pressure: 100 kPa (1 atm)

4. Utilities - Not given

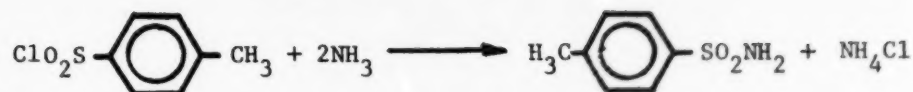
5. Waste Streams - The air vent stream from the gas absorber will contain hydrogen chloride. Barium sulfate and phosphate will precipitate on neutralization of the sulfonating solution. Waste wash water streams may contain small amounts of sulfuric and phosphoric acids and their salts as well as p-toluenesulfonic acids.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 298-99.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 595, 612.

p-Toluenesulfonamide

1. Function - Toluenesulfonamide is prepared by reacting toluenesulfonyl chloride with ammonia.
2. Input Materials - Basis: 1 kg toluenesulfonamide  
Ammonia - 0.1 kg  
Toluenesulfonyl chloride - 1.1 kg  
Catalyst - quantity not given
3. Operating Parameters  
Temperature: room temperature or lower  
Pressure: atmospheric
4. Utilities  
Quantities not given
5. Waste Streams - Hydrogen chloride may appear in the air vent streams as well as ammonia although most of the HCl, reacts with the excess ammonia gas used, to form ammonium chloride. The  $\text{NH}_4\text{Cl}$  will be present in the waste water streams as well as small amounts of toluenesulfonamide.
6. EPA Source Classification Code  
None
7. Reference  
Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 611-613.

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition,  
Interscience Publishers, New York, N.Y., Vol. 19 (1969), p. 255-260.



SECTION X  
XYLENES

XYLENES

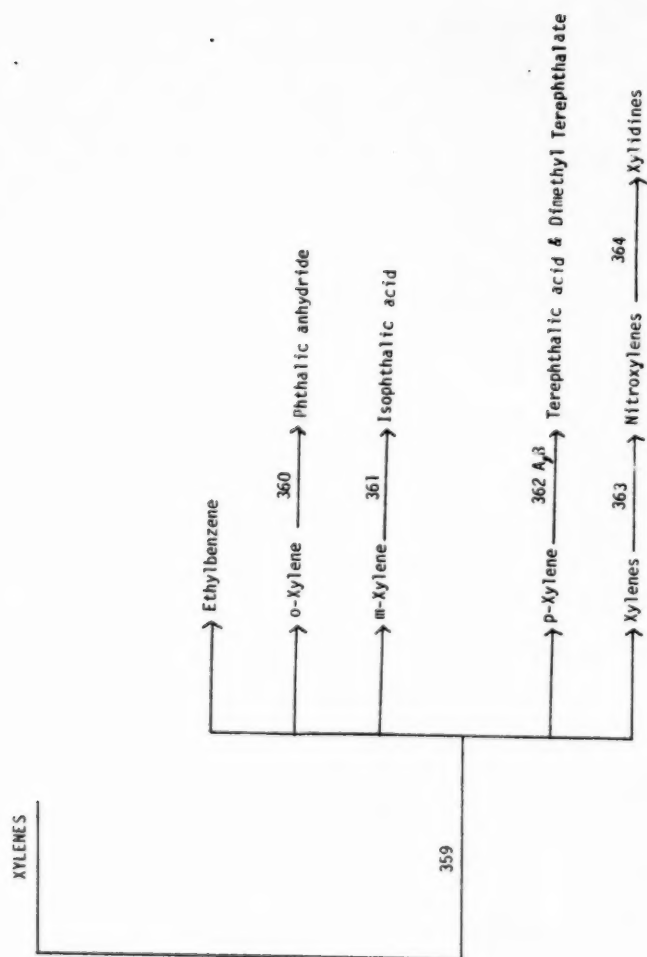


Figure 19. Xylenes Section Chemical Tree

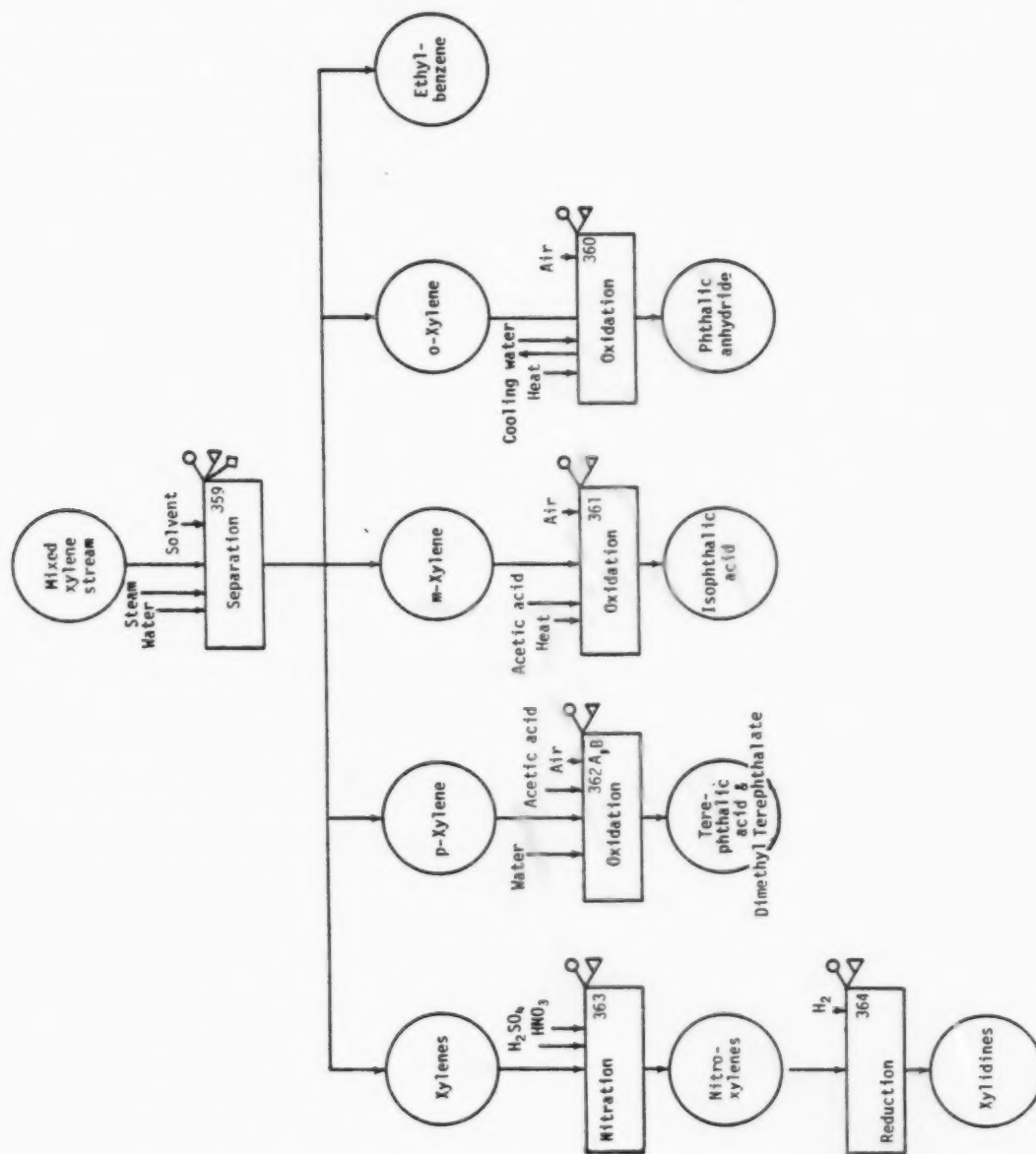


Figure 20. Xylenes Section Process Flow Sheet

o-, m-, and p-Xylenes and Ethyl Benzene

1. Function - Over 90% of the domestic production of xylenes is the result of catalytic reforming or hydroforming of certain petroleum fractions. Disproportionation and transalkylation of toluene is a minor source of xylenes. A typical cut of  $C_8$  stock has the following composition:

|               | Wt. % in<br>distillate | M.P., °C | B.P., °C |
|---------------|------------------------|----------|----------|
| ethyl benzene | 9-13%                  | -95.0    | 136.2    |
| p-xylene      | 17-20%                 | 13.2     | 138.4    |
| m-xylene      | 45-53%                 | -47.9    | 139.1    |
| o-xylene      | 18-24%                 | -25.2    | 144.4    |

By a process termed super-fractionation, ethyl benzene (99.7% purity) can be separated from the xylenes. In addition, o-xylene can be separated from the other xylenes by fractional distillation.

The differences in melting points allow for practical separation of the m- and p-isomers.

The dried feedstock (~ 10 P.P.M.  $H_2O$ ) is cooled to  $-40^{\circ}C$  and passed to a crystallizer at  $-62^{\circ}C$  to  $-66^{\circ}C$ . Crystals of p-xylene formed are centrifuged, partially melted and recrystallized at  $-31^{\circ}C$ . The mother liquor (rich in m-xylene) can be recycled or isomerized to yield more p-xylene.

Isomerization processes may employ a platinum on a silica-alumina support as a catalyst. Isomerization occurs in the vapor

phase in the presence of hydrogen at temperatures around 450°C and pressures in the 10-25 atm range. The product of isomerization is recycled to the crystallization unit.

Other processes of interest in the isolation of xylenes include:

1. Preferential adsorption of p-xylene on a solid absorbent from a mixture of C<sub>8</sub> aromatics (Parex process).

2. Separation of pure m-xylene via sulphonation, formation of clathrates, or formation of an HF·BF<sub>3</sub> complex.

3. Separation of m- and p-isomers by formation of Werner type complexes.

## 2. Input Materials

C<sub>8</sub> aromatics

## 3. Operating Parameters

Separation of ethyl benzene

(Three 200 ft column in series containing 350 plates. Reflux ratio 25:1 to 50:1.)

Crystallization (p-xylenes)

1st - Temperature: -62°C-66°C (144-151°F)  
Pressure: not given

2nd - Temperature: -31°C (88°F)  
Pressure: not given

Isomerization

Temperature: -450°C (842°F)  
Pressure: 1.01-2.53 MPa (10-25 atm)  
Catalyst: Platinum on a silica-alumina support

4. Utilities

Distillation of ethylbenzene and o-xylene: Not given

Crystallization of p-xylene (Chevron Process, Crude Feed)

Basis: 45.4 Gg/yr (100 M lb/yr) capacity

water - 40 dm<sup>3</sup>/s (600 gpm)

steam - 2.3 Gg/hr (5 M lb/hr)

power - 10.8 GJ (3,000 kWh)

Isomerization of m-xylene (alumina-silica catalyst, Crude Feed)

Basis: 45.4 Gg/yr (100 M lb/yr) capacity

water - 44 dm<sup>3</sup>/s (700 gpm)

steam - 7.3 Mg/hr (16,000 lb/hr)

power - 1.4 GJ (400 kWh)

fuel - 30 MW (100 M Btu/hr)

5. Waste Streams

Distillation - Not given.

Crystallization - Sludge 0.3-1.7 m<sup>3</sup>/Mg (100-500 gallons/ton of p-xylene) containing 3g-5kg/m<sup>3</sup> (3-5,000 mg/l) of organic material is produced.

Isomerization - Separator has an off-gas vent that would expel organic vapors.

6. EPA Source Classification Code - None.

7. References

Brownstein, A. M., U. S. Petrochemicals, The Petroleum Publishing Company, Tulsa, Oklahoma, 1972.

Gloyna, E. F., and Ford, D. L., "The Characteristics and Pollution Problems Associated with Petrochemical Wastes", for TWPCA, Contract No. 14-12-461, February, 1970.

Ries, H. C., "Xylenes Separation", Report No. 25, Stanford Research Institute, Menlo Park, California, 1967.

Anon., "Development Document for Effluent Limitations Guidelines and Standards of Performance", prepared for Environmental Protection Agency, Contract No. 68-01-1509, June, 1973.

Austin, G. T., "The Industrially Significant Organic Chemicals - Part 9", "Chemical Engineering," August 5, 1974, p. 99.

Waddams, A. L., Chemicals From Petroleum, 3rd Edition, John Wiley and Sons, New York, N. Y., 1973, p. 209-221.

Phthalic Anhydride (from o-xylene)

1. Function - Phthalic anhydride (PAN) is manufactured by air oxidation of o-xylene in a fixed catalyst bed reactor. Oxidation is achieved by feeding the mixture of vaporized o-xylene and preheated air (1:10) to a reactor containing a  $V_2O_5$  based proprietary catalyst. The reaction takes place at a temperature of  $\sim 550^\circ\text{C}$  with a contact time of the order of .10 to .15 seconds. Heat is removed by circulating molten salts across the reactor. Many plants can operate at will on o-xylene or naphthalene feedstock.

The vapors leaving the reactor are condensed, then melted and fed into a pre-decomposer. In the pre-decomposer maleic and benzoic acid are removed and any phthalic acid present is dehydrated. Final purification is done by distillation in vacuum.

2. Input Materials

|          |                                                  |
|----------|--------------------------------------------------|
| o-xylene | 975 kg/metric ton product                        |
| air      | 25,000 m <sup>3</sup> at 15°C/metric ton product |

3. Operating Parameters

|                     |                                        |
|---------------------|----------------------------------------|
| Temperature:        | 550°C (1022°F)                         |
| Pressure:           | not given                              |
| Catalyst:           | proprietary catalyst based on $V_2O_5$ |
| Contact Time:       | 0.10 to 0.15 sec                       |
| Av. Plant Capacity: | 18 to 45 million kg/yr                 |



4. Utilities - not given
5. Waste Streams - Waste gas - Most waste gas is scrubbed with water. Removal rates have been shown to be in excess of 99% of all organic acids, however total aldehydes removal is poor with concentrations in the effluent varying between 8 and 26 ppm as formaldehyde. The scrubbing water discharges at 115 - 130°F with 1.7 - 2.5% total acidity as maleic acid.

A phthalic anhydride plant producing 100 million pounds of PAN a year could have a scrubber effluent with an ultimate oxygen demand of from 400 to in excess of 1200 lbs/hr.

6. EPA Source Classification Code - None
7. References

Sittig, M., Pollution Control in the Organic Chemical Industry, Noyes Data Corp., Park Ridge, N. J., 1974, p. 186-188.

Fawcett, R. L., "Air Pollution Potential of Phthalic Anhydride Manufacture," Journal of the Air Pollution Control Association, 20 (7): 461-465, 1970.

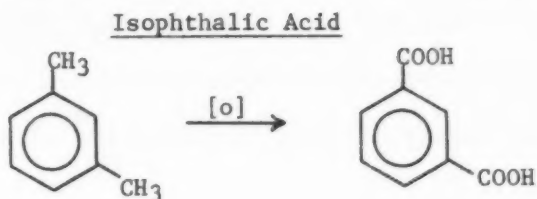
Austin, G. T., "Industrially Significant Organic Chemicals - Part 8," "Chemical Engineering", July 22, 1974, p. 109-110.

"1973 Petrochemicals Handbook", "Hydrocarbon Processing", November, 1973, p. 159-160.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Wiley and Sons, New York, N. Y., 1973, p. 228-230.

Lowenheim, F. A. and Moran, M. K., Industrial Chemicals, 4th Edition, John Wiley and Sons, New York, N. Y., 1975, p. 661-664.

Hedley, W. H. et al., "Potential Pollutants from Petrochemical Processes", Prepared for Control Systems Laboratory, NERC, Environmental Protection Agency, Contract No. 68-02-0226, Task No. 9, 1973, p. 95-96.

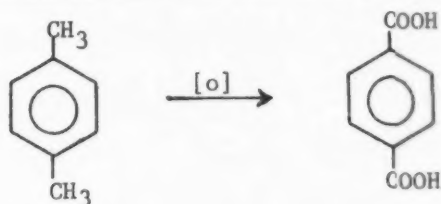


1. Function - As of 1971 Amoco and Arco were the only two producers of isophthalic acid in the U.S. In the Amoco process m-xylene is oxidized in the liquid phase at 150-250°C and a pressure of 15-30 atm. Air is used as the oxidizing agent and the reaction is carried out in acetic acid as solvent, in the presence of a bromine-promoted cobalt salt as catalyst. The isophthalic acid produced will contain varying amounts of terephthalic acid depending on the purity of the m-xylene feedstock.
2. Input Materials  
m-xylene  
Acetic acid  
Catalyst
3. Operating Parameters  
Temperature: 150-250°C (301-481°F)  
Pressure: 1.52-3.04 MPa (15-30 atm)  
Catalyst: cobalt salt activated by bromine
4. Utilities - not given
5. Waste Streams - Potential water wastes are IPA, terephthalic acid, and acetic acid.
6. EPA Source Classification Code - None

7. References

Hedley, W. H., et. al., Potential Pollutants from Petrochemical Processes, Prepared for Control Systems Laboratory, NERC, Environmental Protection Agency, Contract No. 68-02-0226, Task No. 9, 1973.

Waddams, A. L., Chemicals From Petroleum, 3rd Edition, John Wiley and Sons, New York, N. Y., 1973 , p. 232-235.

Terephthalic Acid and Dimethyl Terephthalate

1. Function - Terephthalic acid (TPA) is produced by the air oxidation of p-xylene in the liquid phase.

p-Xylene dissolved in acetic acid reacts with air in the presence of a cobalt proprietary catalyst in a reactor at 200°C and 400 p.s.i. The hot slurry from the reactor effluents is fed into a crystallizer. Acetic acid, unreacted p-xylene and water are removed at this step and by further centrifugation. Acetic acid and p-xylene are recycled. The crude TPA is leached with acetic acid at high temperature. The resulting TPA of better than 99% purity is washed with hot water to remove traces of catalyst and acetic acid. Subsequent hydrogenation in fixed-bed reactors, crystallization and drying yield fiber grade TPA. A new route to TPA involves the ammoxidation of p-xylene and the subsequent hydrolysis of terephthalonitrile to terephthalic acid. The Hercules-Witten process produces dimethyl terephthalate from p-xylene without isolation of TPA.

2. Input Materials

p-xylene - 680 kg/metric ton polymer grade TPA

air - not given

acetic acid - not given

3. Operating Parameters

Temperature: 200°C (392°F)  
Pressure: 2.76 MPa (27.2 atm)  
Catalyst: Bromine promoted cobalt catalyst

4. Utilities - not given

5. Waste Streams - Off-gas from scrubber contain some organic vapors; wastewaters contain acetic acid, traces of catalyst, and terephthalic acid.

Water flow rate -  $3.62 \times 10^{-4}$  -  $9.09 \times 10^{-3}$  m/kg  
(86.8 - 2180 gal/ton)

|                  |                                 |                          |
|------------------|---------------------------------|--------------------------|
| COD              | 5,400 - 24,950 g/m <sup>3</sup> | (1.95 - 227 lb/1000 lb)  |
| BOD <sub>5</sub> | 3,600 - 7,500 g/m <sup>3</sup>  | (1.30 - 68.3 lb/1000 lb) |
| TOC              | 4,200 - 3,730 g/m <sup>3</sup>  | (1.52 - 34 lb/1000 lb)   |

6. EPA Source Classification Code - None

7. References

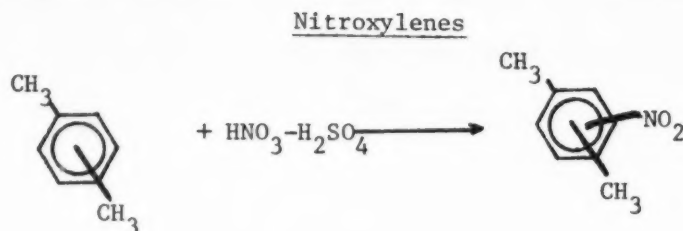
Sittig, M., Pollution Control in the Organic Chemical Industry  
Noyes Data, Park Ridge, N.J., 1974, p. 198-203.

"1973 Petrochemical Handbook", "Hydrocarbon Processing", November, 1973, p. 183-185.

Hedley, W. H., et. al., Potential Pollutants in the Petrochemical Processes, Prepared for Control Systems Laboratory, NERC, Environmental Protection Agency, Contract No. 68-02-0226, Task No. 9, 1973.

Waddams, A. L., Chemicals from Petroleum, 3rd Edition, John Wiley and Sons, 1973, p. 232-237.

Lowenheim, F. A., and Moran, M. K., Industrial Chemicals, 4th  
Edition, John Wiley and Sons, 1975, p. 807-813.



1. Function - Xylenes, o-, m- or p-isomers, can be nitrated to place nitro groups on the benzene ring. Ortho-xylene gives the 4-nitro and the 4,6-dinitro isomers; meta-xylene gives the 4-nitro isomer, and para-xylene the 2,3-dinitro- or 2,6-dinitro-p-xylene, or the 2-nitro-p-xylene.

The extent of nitration, the number of nitro groups placed in the ring, is a function of acid strength and temperature. The extent of side chain oxidation is dependent on the same two factors; therefore, with polynitrated products a compromise must be reached.

Mononitration of xylenes is carried out near room temperature, 25°C (77°F) with a mixture of nitric 30% and sulfuric (55%) acids and at atmospheric pressure.

2. Input Materials

Xylenes

Nitric-sulfuric acid mixture

3. Operating Parameters

Temperature - 25-40°C (77-104°F)

Pressure - 100 kPa (1 atm)

4. Utilities - Not given



5. Waste Streams - Spent acid is recovered and recycled to the system.

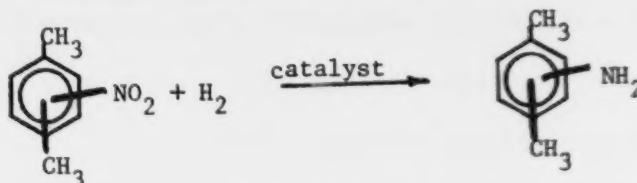
Air emissions from the reactor may contain oxides of nitrogen. Waste water from the product washing procedure contains sodium carbonate, some nitroxylenes and nitrate salts.

6. EPA Source Classification Code - None

7. References

Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers, New York, N.Y., Vol. 22 (1970), p. 484.

Chemical Technology, Barnes and Noble Books, New York, N.Y., Vol. 4 (1972), p. 172-174.

Xylidines (reduction of nitroxyls)

1. Function - The xylidines are made by the reduction of nitroxyls.

The only technical process used at present is hydrogen reduction.

A molybdenum sulfide catalyst is used for this reaction.

2. Input Materials

Nitroxyls

Hydrogen

MoS<sub>3</sub> on an inert support

3. Operating Parameters

Temperature - 165-170°C (330-340°F)

Pressure - 20.7 MPa (205 atm)

Catalyst - MoS<sub>3</sub>

Nitroxylene feed - 0.44 vols/vol catalyst/hr.

Recycle feed - 1.2-1.6 vols/vol

Recycle gas - 80-85% H<sub>2</sub> and 0.6% H<sub>2</sub>S

4. Utilities - Not given

5. Waste Streams - Waste water from product wash contains sodium carbonate.

Vents emit some hydrogen.

6. EPA Source Classification Code - None

7. Reference

Brown, C. L., and Smith, W. W., "Production of Xylidines by High Pressure Hydrogenation," Ind. Eng. Chem., Vol. 40, (1948), pp. 1538-42.

APPENDIX A

INDUSTRIAL CHEMICALS AND SOLVENTS GLOSSARY

Table A-1 lists specific industrial compounds and their uses. Also included are the major producers listed in alphabetical order for each compound, the plant locations, plant capacities, and total annual production where available. Capacities given are for 1975 and total chemical production is for the specific year noted. Capacity and production estimates are given in millions of kilograms per year (MM kg) and millions of pounds per year (MM lbs).

### References

1. Hawley, G. G. (ed.). The Condensed Chemical Dictionary. 8th Edition, Van Nostrand Reinhold Company, 1971.
2. Staff. Directory of Chemical Producers - U.S.A. Chemical Information Services, Stanford Research Institute, Menlo Park (California), 1975.
3. Staff. Chem. Sources. Directories Publishing Co., Flemington, New Jersey, 13th Edition, 1972.
4. Staff. "Recession Stifles Output of Top 50 Chemicals." Chemical and Engineering News, American Chemical Society, May 5, 1975, p. 31.
5. Staff. "Facts and Figures - The U.S. Chemical Industry." Chemical and Engineering News, American Chemical Society, June 2, 1975, p. 33.

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Table A-1. INDUSTRIAL CHEMICALS AND SOLVENTS.

| Chemical     | Use(s)                                                                                                                                                                                                                                                                              | Manufacturer(s)                                                                                                                                                                                                                                                                                               | Location(s)                                                                                                                                     | 1975<br>Capacity<br>MM KG (MM lb)                                           | Total<br>Production<br>MM KG (MM lb)<br>for year of estimate |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------|
| Arenaphthene | Dye intermediate;<br>pharmaceuticals;<br>insecticide; fungicide; plastic                                                                                                                                                                                                            | Hoffmann - La Roche, Inc., Burdick & Jackson Labs., Inc., subsid.                                                                                                                                                                                                                                             | Muskegon, Mich.                                                                                                                                 | -                                                                           | -                                                            |
| Acetal       | Solvent; cosmetics;<br>organic synthesis;<br>perfumes; flavors                                                                                                                                                                                                                      | Fritzsche Dodge & Olcott Inc.                                                                                                                                                                                                                                                                                 | East Hanover, N.J.                                                                                                                              | -                                                                           | -                                                            |
| Acetaldehyde | Acetic acid; acetic anhydride; butanol; 2-ethylhexanol; peracetic acid; pentamethylol; pyridines; chloral; 1,3-butylene glycol; trimethylpropane manufacturing intermediate                                                                                                         | Celanese Corp. -<br>Celanese Chem. Co., div.<br>Eastman Kodak Co. -<br>Eastman Chem. Products, Inc., subsid. Texas<br>Eastman Co., div.<br>Monsanto Co. - Monsanto Polymer & Petrochems. Co.<br>Publicker Indust. Inc.<br>Shell Chem. Co. -<br>Bace Chems.<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Bay City, Tex.<br>Clear Lake, Tex.<br>Pampa, Tex.<br>Longview, Tex.<br>Texas City, Tex.<br>Philadelphia, Pa.<br>Norco, La.<br>Institute & South | 90.8 (200)<br>-<br>217 (480)<br>2.3 (5)<br>2.3 (5)<br>2.3 (5)<br>90.8 (200) | 731.6 (1611.8)-1970                                          |
| Acetaldehyde | Rubber accelerators;<br>age resisters; synthesis;<br>perfumery; engraving; fire<br>floatation; solvent; solvent mixture for cellulose acetate; fungicides;<br>organic synthesis;<br>printer's rollers; cad-<br>mium plating; dyes;<br>drugs; dental anesthetant; synthetic polymers | Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                                                                                                                                                                                               | Institute & South<br>Charleston, W. Va.                                                                                                         | -                                                                           | -                                                            |
| Acetaldehyde |                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                               |                                                                                                                                                 | Total =<br>674.2 (1485)                                                     |                                                              |

Table A-1. (Continued)

| Chemical    | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                        | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                          | Location(s) <sup>2,3</sup>                                                                                                                                                                                                 | 1975 Capacity <sup>2</sup><br>MM kg (NW lb)                                                                                                                              | Total <sup>4,5</sup><br>Production<br>MM kg (NW lb)<br>for year of estimate |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Acetamide   | Organic synthesis<br>(reactant, solvent,<br>peroxide stabilizer);<br>general solvent; lac-<br>quers; explosives;<br>soldering flux;<br>hygroscopic agent;<br>wetting agent;<br>penetrating agent                                                                                                                                                          | Heico, Inc.<br>Mallinckrodt, Inc. -<br>Indust. Chem. Div.                                                                                                                                                                                                                                                                                                                               | Delaware Water<br>Gap, Pa.<br>St. Louis, Mo.                                                                                                                                                                               | -<br>-                                                                                                                                                                   | -                                                                           |
|             | Rubber accelerators;<br>inhibitor in hydro-<br>gen peroxide; stabilizer<br>for cellulose acetate;<br>cellulose acetate<br>intermediate (paranitro-<br>aniline, parathionace-<br>tanilide, parathylene-<br>dianiline); synthetic cam-<br>phor; pharmaceutical<br>chemicals; dyestuffs;<br>precursor in penicillin<br>manufacture; medicine<br>(antiseptic) | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. Tennessee<br>Eastman Co., div.<br>Merck & Co. Inc. -<br>Merck Chem. Div.<br>Salisbury Labs<br>Syntex Corp. - Anapahne<br>Chems. Div.                                                                                                                                                                                    | Kingsport, Tenn.<br><br>Altany, Ga.<br>Charles City, Iowa<br>Newport, Tenn.                                                                                                                                                | -<br>-<br>-<br>-                                                                                                                                                         | -                                                                           |
| Acetic acid | Acetic anhydride, cellu-<br>lose acetate, and vinyl<br>acetate monomers; acetic<br>acid; cellulose acetate;<br>production of plastics;<br>pharmaceuticals, dyes;<br>insecticides, photo-<br>graphic chemicals, etc.;<br>food additive (as vine-<br>gar); natural latex<br>coagulant; oil-well<br>acidizer; textile<br>printing                            | Borden Inc. - Borden<br>Chem. Div. Ferrochems.<br>Celanese Corp. - Cella-<br>nese Chem. Co., div.<br><br>Eastman Kodak Co. -<br>Eastman Chem. Prod. Inc.,<br>subsid. - Tenn. Eastman<br>Co., div.<br>PMC Corp. - Chem. Group<br>Indust. Chem. Div.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochems. Co.<br>Publicker Indust. Co.<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Geismar, La.<br>Bay City, Texas<br>Bishop, Tex.<br>Clear Lake, Tex.<br>Fampa, Tex.<br>Kingsport, Tenn.<br><br>Bayport, Tex.<br>Texas City, Tex.<br>Philadelphia, Pa.<br>Brownsville, Tex.<br>Tart, La.<br>Texas City, Tex. | 52.2 (115)<br>-<br>50 (110)<br>181.6 (400)<br>250 (550)<br>181.6 (400)<br><br>18.2 (40)<br>181.6 (400)<br>36.3 (80)<br>268 (590)<br>41 (90)<br>45.8 (100)<br>1305 (2875) | 930.7 (2050)-1971                                                           |

Table A-1. (Continued)

| Chemical            | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                 | Location(s) <sup>2,3</sup>                                                                                                                       | 1975<br>Capacity <sup>2</sup><br>MM kg (MM lb)                                           | Totals <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>For year of estimate |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Acetic<br>anhydride | Cellulose acetate fi-<br>bers and plastics; vinyl<br>acetate; dehydrating<br>and acetylating agent in<br>production of pharma-<br>ceuticals, dyes, per-<br>fumes, explosives, etc.;<br>aspirin                                                                                                                                                                               | Celanese Corp. - Cella-<br>nese Chem. Co., div.<br>Celanese Fibers Co., div.                                                                                                                                                                                                                                                                                                                                                   | Pampa, Tex.<br>Cumberland, Md.<br>Narrows, Va.<br>Rock Hill, S.C.<br>Rome, Ga.                                                                   | 386 (850)                                                                                | 708.5 (1560.6)-1972                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                              | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc.<br>FMC Corp. - Chem. Group<br>Indust. Chem. Div.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                                                                                      | Kingsport, Tenn.<br>Meadville, Pa.<br>Brownsville, Tex.<br>Texas City, Tex.                                                                      | 272.4 (600)<br>27.2 (60)<br>102 (225)<br>Total =<br>787.7 (1735)                         |                                                                              |
| Acetone             | Chemicals (methyl iso-<br>butyl ketone, methyl<br>isobutyl carbinol<br>ethyl methacrylate<br>vinylidene chloride, sol-<br>vents; lacquer sol-<br>vents; toluene; dry<br>parts of precision<br>equipment; solvent for<br>potassium iodide &<br>permanganate; deluste-<br>rant for cellulose<br>acetate fibers; speci-<br>fication testing of<br>vulcanized rubber<br>products | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>Clark Oil & Refining<br>Corp. - Clark Chem.<br>Corp., subsid.<br>Dixie Chem. Co.<br>Dow Chem. U.S.A.<br>Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. - Tennes-<br>see Eastman Co., div.<br>Exxon Corp. - Exxon<br>Chem. Co., div. - Exxon<br>Chem. Co. U.S.A.<br>Georgia-Pacific Corp. -<br>Chem. Div.<br>The Goodyear Tire & Rub-<br>ber Co. - Chem. Div. | Frankford, Pa.<br>Blue Island, Ill.<br>Rayport, Tex.<br>Cyster Creek, Tex.<br>Kingsport, Tenn.<br>Rayway, N.J.<br>Piquette, La.<br>Rayport, Tex. | 143 (315)<br>24 (53)<br>11 (24)<br>109 (240)<br>36 (80)<br>63.6 (140)<br>79.1 (172)<br>- | 902.2 (1987.2)-1973                                                          |



Table A-1. (Continued)

| Chemical               | Usage <sup>1</sup>                                                                                                                                                                                                      | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                   | 1975 Capacity <sup>2</sup><br>MM kg (MM lb.)                                                                                                                                                         | Total <sup>2,5</sup><br>Production<br>MM kg (MM lb.)<br>for year of estimate |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Acetone<br>(continued) | (see previous page)                                                                                                                                                                                                     | Monsanto Co. - Monsanto's<br>Polymers & Petrochemicals Co.<br>Oxirane Chem. Co.<br>Publicker Indust. Inc.<br>Shell Chem. Co. -<br>Base Chems.<br>Skelly Oil Co.<br>Standard Oil of Calif. -<br>Chevron Chem. Co. sub-<br>sidi. Oronite Additives<br>& Indust. Chems. Div. -<br>Indust. Chems.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Union Carbide Carbide,<br>Inc., subsidi.<br>United States Steel Corp.<br>USS Chems., div.<br>E. I. du Pont de Nemours<br>& Co. Inc. - Industrial<br>Chems. Dept.<br>Rohm & Haas Co. - Rohm &<br>Haas Texas Inc., subsidi.<br>Eastman Kodak Co. - East-<br>man Chem. Products, Inc.,<br>subsidi., Texas Eastman<br>Co., div.<br>The Standard Oil Co.<br>(Ohio) - Vistron Corp.,<br>subsidi., Chems. Dept. | Chocolate Bayou,<br>Tex.<br>Bayport, Tex.<br>Philadelphia, Pa.<br>Deer Park, Tex.<br>Dominquez, Calif.<br>Morco, Ia.<br>El Dorado, Kans.<br>Richmond, Calif.<br>Bount Brook, N.J.<br>Institute & South<br>Charleston, W. Va.<br>Texas City, Tex.<br>Peneulas, P.R.<br>Haverhill, Ohio<br>Belle, W. Va.<br>Deer Park, Texas<br>Longview, Tex.<br>Mapleton, Ill.<br>Lima, Ohio | 129.6 (270)<br>18.2 (40)<br>15.9 (35)<br>181.6 (400)<br>45.4 (100)<br>45.4 (100)<br>25.9 (57)<br>15 (33)<br>31 (70)<br>68.1 (150)<br>50 (110)<br>54.5 (120)<br>76.3 (168)<br>Total =<br>129.4 (2697) | 285.2 (540)-1969                                                             |
| Acetone<br>Cyanhydrin  | Insecticides: inter-<br>mediate for organic<br>synthesis, especially<br>methyl methacrylate                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                      |                                                                              |
| Acetonitrile           | Solvent in hydro-<br>carbon processing<br>intermediate for ma-<br>diene; specialty sol-<br>vent; intermediate;<br>separation of fatty<br>acids from vegetable<br>oils; manufacture of<br>synthetic pharma-<br>ceuticals |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                      |                                                                              |

Table A-1. (Continued)

| Chemical      | Usage 1                                                                                                                                                                                          | Manufacturer(s) 2,3                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Location(s) 2,3                                                                                                                                                                   | Total Capacity, MM KS (MW 10)                                                                      | Total Production, MM KS (MW 10) per year of estimate                 |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Aceto-phenone | Perfumery; solvent; intermediate for pharmaceuticals, resins, etc.; flavoring                                                                                                                    | Alfred Mear Corp. Specialty Chem.<br>Skelly Oil Co.<br>Universal Oil Products Co. - Chems. & Plastics Group - Chem. Div.<br>Chemical Use<br>Airco, Inc.                                                                                                                                                                                                                                                                                                                                         | Frankfort, Pa.<br>El Dorado, Kans.<br>East Rutherford N.J.<br>Calvert City, Ky.<br>Louisville, Ky.<br>Hometown, Pa.                                                               | -<br>-<br>-<br>36.3 (80)<br>10.3 (24)                                                              | -<br>-<br>-<br>230.2 (507) - 1974<br>(chemical and non-chemical use) |
| Acetylene     | Vinyl chloride & vinylidene chloride; vinyl acetate; welding & cutting metals; neoprene; acrylonitrile; acrylates; polyethylene; chloroethylene; vinyl octadecene; tetrahydrofuran; carbon black | Air Products & Chems., Inc., Specialty Gas Dept.<br>Monsanto Corp. - Indust. Gases Div.<br>Faw Chem. U.S.A.<br>Gaspro Inc.<br>Liquid Air Corp. of North America - Southwestern Region<br>Monsanto, Inc.<br>Northern Gases, Inc.<br>Occidental Petroleum Corp. - Harker Chem. Corp.<br>Fluor Corp. - Fluorocarbon Div.<br>Electrochemical & Specialty Chems. Div.<br>Rohm & Haas Co. - Rohm & Haas Texas Inc., subsid.<br>Solex, Inc.<br>Tenneco Inc. - Tenneco Chems., Organics & Polymers Div. | Fryer, Okla.<br>Freeport, Tex.<br>Honolulu, Hawaii<br>Houston, Tex.<br>Geismar, La.<br>Waukegan, Wis.<br>Tacoma, Wash.<br>Deer Park, Tex.<br>Chattanooga, Tenn.<br>Houston, Texas | 0.5 (1)<br>6.8 (15)<br>40.5 (41)<br>-<br>81.7 (18)<br>4.5 (10)<br>-<br>15.4 (34)<br>-<br>45.4 (10) | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-                  |

Table A-1. (Continued)

| Chemical                 | Usage:<br>(see previous page) | Manufacturer(s):                                                                                | Location(s):                                                                                                                                                                                                                                                              | Total<br>Capacity<br>MW (MW lb)                                         | Total<br>Production<br>MW (MW lb)<br>for year of estimate<br>(see previous page) |
|--------------------------|-------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Acetylene<br>(continued) |                               | Union Carbide Corp. -<br>Chem. & Plastics<br>Div.                                               | Ashland, Ohio<br>Institute & Tech.<br>Charleston, S. Va.                                                                                                                                                                                                                  | 3.0 (75)<br>15.3 (13)                                                   | 3.0 (75)<br>15.3 (13)                                                            |
|                          |                               | Union Carbide Caribe,<br>Inc., subsid.                                                          | Seadrift, Tex.<br>Taft, La.<br>Texas City, Tex.<br>Fenuelas, P.R.                                                                                                                                                                                                         | 3.0 (75)<br>6.0 (13)<br>8.2 (13)<br>36.3 (50)                           | 3.0 (75)<br>6.0 (13)<br>8.2 (13)<br>36.3 (50)                                    |
| Acetylene<br>(continued) |                               | Non-Chemical Usage<br>Airco, Inc. - Arco<br>Indust. Gases Div.<br>Air Products & Chem.,<br>Inc. | Houston, Tex.<br>Altam, Ja.<br>Blandenburg, Md.<br>Creston, Pa.<br>Dallas, Tex.<br>Granite City, Ill.<br>Greensboro, N.C.<br>Hampton, Va.<br>Iselin, N.J.<br>Kingsport, Tenn.<br>Memphis, Tenn.<br>Omaha, Neb.<br>Pittsburgh, Pa.<br>Rapid City, S.D.<br>New Orleans, La. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-          |
|                          |                               | American Cyanamid Co. -<br>Specialty Gas Dept. -<br>Indust. Chem. & Plastics<br>Div.            | Norristown, Pa.<br>Athens, Tex.<br>Belton, Tex.<br>Cleveland, Ohio<br>Columbus, Ohio<br>Conshohocken, Pa.<br>Dallas, Tex.<br>Denver, Colo.<br>Detroit, Mich.                                                                                                              | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-                               | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-                                        |
|                          |                               | Burdett Oxygen Co.<br>Paul Carroll Oxygen Co.<br>Chematron Corp. - Indust.<br>Gases Div.        | -<br>-<br>-<br>-                                                                                                                                                                                                                                                          | -<br>-<br>-<br>-                                                        | -<br>-<br>-<br>-                                                                 |

Table A-1. (Continued)

| Chemical                 | Usage <sup>1</sup>  | Manufacturer(s) <sup>2,3</sup>                                | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                      | 1970<br>Capacity <sup>2</sup><br>MM Bbl (MM lb)                         | Total <sup>1,2</sup><br>Production<br>MM Bbl (MM lb)<br>for year of estimate |
|--------------------------|---------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Acetylene<br>(continued) | (see previous page) | Chemetron Corp. (cont'd)                                      | Evansville, Ind.<br>Hodgkins, Ill.<br>Jackson, Miss.<br>Jacksonville, Fla.<br>Knoxville, Tenn.<br>McKees Rocks, Pa.<br>Memphis, Tenn.<br>Meriden, Conn.<br>New Orleans, La.<br>North Grafton, Mass.<br>Peoria, Ill.<br>Pryor, Okla.<br>St. Paul, Minn.<br>Southaven, Miss.<br>Tampa, Fla.<br>Ewa (Oahu), Hawaii | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | (see previous page)                                                          |
|                          |                     | Welding & Indust.<br>Products, Ltd. - subsid.                 | Tyler, Tex.                                                                                                                                                                                                                                                                                                     | -                                                                       |                                                                              |
|                          |                     | East Texas Oxygen Co.                                         | Hutchinson, Kans.                                                                                                                                                                                                                                                                                               | -                                                                       |                                                                              |
|                          |                     | Kansas Oxygen, Inc.                                           | Anchorage, Alas.                                                                                                                                                                                                                                                                                                | -                                                                       |                                                                              |
|                          |                     | Liquid Air Corp. of North<br>America - Northwestern<br>Region | Boise, Idaho<br>Fairbanks, Alas.<br>Medford, Ore.<br>Missoula, Mont.<br>Portland, Ore.<br>Spokane, Wash.                                                                                                                                                                                                        | -<br>-<br>-<br>-<br>-<br>-                                              |                                                                              |
|                          |                     | - Southeastern Region                                         | Augusta, Ga.<br>Birmingham, Ala.<br>Lake Charles, La.<br>Orlando, Fla.                                                                                                                                                                                                                                          | -<br>-<br>-<br>-                                                        |                                                                              |
|                          |                     | - Southwestern Region                                         | Abilene, Tex.<br>Lubbock, Tex.<br>Odessa, Tex.<br>Phoenix, Ariz.<br>Tucson, Ariz.                                                                                                                                                                                                                               | -<br>-<br>-<br>-<br>-                                                   |                                                                              |
|                          |                     | - Western Region                                              | Las Vegas, Nev.<br>Reno, Nev.<br>Sacramento, Calif.<br>San Bernardino,<br>Calif.<br>Santa Fe Springs,<br>Calif.<br>Union City, Calif.                                                                                                                                                                           | -<br>-<br>-<br>-<br>-<br>-                                              |                                                                              |
|                          |                     | Manitowoc Gases, Inc.                                         | Manitowoc, Wisc.                                                                                                                                                                                                                                                                                                | -                                                                       |                                                                              |

Table A-1. (Continued)

| <u>Chemical</u>          | <u>Usage 1</u>                                                                                                                                                                                          | <u>Manufacturer(s) 2+3</u>                                                                                                                                                  | <u>Location(s) 2+3</u>                                                                                                                                                                                                                                                                                                                                                                                                               | Capacity, <sup>2</sup><br>MM KG. (MW lb)                                                    | 1975<br>Production <sup>1</sup><br>MM KG. (MW lb)<br>for year of estimate                   | Total, <sup>2,3</sup> |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------|
|                          | (see previous page)                                                                                                                                                                                     |                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                      | -                                                                                           | (see previous page)                                                                         |                       |
| Acetylene<br>(Continued) |                                                                                                                                                                                                         | Northern Gases, Inc.<br>Pacific Oxygen Co.<br>Serox, Inc.<br>Union Carbide Corp. -<br>Ferroc alloys Div.<br>Linde Div.                                                      | Maukasha, Wisc.<br>Oakland, Calif.<br>Greenville, S.C.<br><br>Ashtabula, Ohio<br>Albany, N.Y.<br>Altoona, Pa.<br>Altoona, Pa.<br>Amarillo, Tex.<br>Baltimore, Md.<br>Billings, Mont.<br>Birmingham, Ala.<br>Boise, Idaho<br>Butte, Mont.<br>Carter Lake, Iowa<br>Casper, Wyo.<br>Charlotte, N.C.<br>Columbus, Ohio<br>Dallas, Tex.<br>Denver, Colo.<br>Des Moines, Iowa<br>Duluth, Minn.<br>East Buffalo, N.Y.<br>East Chicago, Ind. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | -1974                 |
| Acrolein                 | Intermediate for synthetic glycerol, polyurethane, polyester resins, methionine, pharmaceuticals; herbicide, tear gas                                                                                   | Shell Chem. Co. -<br>Base Chems.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                         | Taft, La.                                                                                                                                                                                                                                                                                                                                                                                                                            | -                                                                                           | -                                                                                           | 27.7 (61)             |
| Acrylamide               | Synthesis of dyes, etc.; polymers or copolymers as plastics, adhesives, paper & textile sizes, soil conditioning agents; flocculants; sewage & waste treatment; ore processing; permanent press fabrics | American Cyanamid Co. -<br>Indus. Chems. & Plastics Div.<br>Bio-Rad Lab<br>Dow Chem. U.S.A.<br>The Standard Oil Co.<br>(Ohio) - Visking Corp.,<br>subsidiary - Chems. Dept. | Linden, N.J.<br>New Orleans, La.<br><br>Richmond, Calif.<br>Midland, Mich.<br>Lima, Ohio                                                                                                                                                                                                                                                                                                                                             | -<br>-<br>-<br>-<br>-                                                                       | -                                                                                           | 18.2 (40)             |

Table A-1. (Continued)

| Chemical      | Usage <sup>1</sup>                                                                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                     | Location(s) <sup>2,3</sup>                               | 1976<br>Capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>2,3</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Acrylic acid  | Monomer for polyacrylics & polymethacrylic acids & other acrylic polymers                                                                                                                                                                    | American Aniline & Extract Co., Inc.                                               | Philadelphia, Pa.                                        | -                                              | 37.5 (82.5) -1968                                                           |
|               |                                                                                                                                                                                                                                              | Celanese Corp. - Celanese Chem. Co., div.                                          | Clear Lake, Tex.<br>Pampa, Tex.                          | 100 (220)<br>35.3 (80)                         |                                                                             |
|               |                                                                                                                                                                                                                                              | Dow Badische Co.                                                                   | Freeport, Tex.                                           | 18.2 (40)                                      |                                                                             |
| Acrylonitrile | Acrylic & methacrylic fibers & high-strength plastics; ABS; acrylic emulsions; acrylic cements; nitrile rubber; cyanoethylation of cotton; synthetic soil blocks (acrylonitrile polymerized in wood pulp); organic synthesis; grain fumigant | Rohm & Haas Co., Rohm & Haas Texas Inc., subsid.                                   | Deer Park, Tex.                                          | 181.6 (400)                                    |                                                                             |
|               |                                                                                                                                                                                                                                              | Union Carbide Corp. - Chems. & Plastics Div.                                       | Taft, La.                                                | 90.8 (200)<br>Total = 431.3 (950)              |                                                                             |
|               |                                                                                                                                                                                                                                              | American Cyanamid Co. - Indust. Chems. & Plastics Div.                             | New Orleans, La.                                         | 90.8 (200)                                     | 614.2 (1352.9) -1973                                                        |
| Adipic acid   | Manufacture of nylon & polyurethane foams; preparation of esters for use as plasticizers & lubricants; ingredient of foods, as acidulant; insecticides; adhesives                                                                            | E. I. du Pont de Nemours & Co., Inc. - Elastomer Chems. Dept. Indust. Chems. Dept. | Beaumont, Tex.<br>Memphis, Tenn.<br>Chocolata Bayou, La. | 136.2 (300)<br>113.5 (250)<br>208.5 (460)      |                                                                             |
|               |                                                                                                                                                                                                                                              | Monsanto Co. - Monsanto Polymers & Petrochems. Co.                                 | Lima, Ohio                                               | 177 (390)<br>Total = 728.4 (1600)              |                                                                             |
|               |                                                                                                                                                                                                                                              | The Standard Oil Co. (Ohio) - Vistron Corp., subsid. - Chems. Dept.                | Hopewell, Va.<br>Bay City, Tex.                          | 11.3 (25)<br>56.7 (125)                        | 626.5 (1380) -1972                                                          |
| Adipic acid   | Manufacture of nylon & polyurethane foams; preparation of esters for use as plasticizers & lubricants; ingredient of foods, as acidulant; insecticides; adhesives                                                                            | Celanese Corp. - Celanese Chem. Co., div.                                          | Orange, Tex.<br>Victoria, Tex.                           | 136.2 (300)<br>136.2 (300)                     |                                                                             |
|               |                                                                                                                                                                                                                                              | E. I. du Pont de Nemours & Co., Inc. - Plastics Dept.                              | Odessa, Tex.                                             | 36.3 (80)                                      |                                                                             |
|               |                                                                                                                                                                                                                                              | El Paso Natural Gas Co. - El Paso Products Co., subsid.                            |                                                          |                                                |                                                                             |

Table A-1. (Continued)

| Chemical                       | Use <sup>1</sup>                                                                                                                                                         | Manufacturer(s) <sup>2,3</sup>                                                                                                                           | Location(s) <sup>2,3</sup>                                                                        | 1975 Capacity <sup>2</sup><br>MM kg (MM lb)       | Total <sup>2,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------------------------------------|
| Adipic acid<br>(continued)     | (see previous page)                                                                                                                                                      | Monsanto Co. - Monsanto Indust. Chems. Co. -<br>Monsanto Textiles Co.                                                                                    | Luling, La.<br>Pensacola, Fla.                                                                    | 27.2 (60)<br>255 (562)<br>Total =<br>659.2 (1452) | (see previous page)                                                         |
| Alkyl-naphthalenes<br>(methyl) | Organic synthesis;<br>insecticides                                                                                                                                       | Crowley Hydrocarbon Chems., Inc.                                                                                                                         | Houston, Tex.<br>Kent, Ohio<br>Okla.<br>Pittsboro, N.J.<br>Pottsville, Pa.<br>Pottsville, W. Va.  | -<br>-<br>-<br>-<br>-<br>-                        | -                                                                           |
| Allyl alcohol                  | Esters for use in resins & plasticizers; intermediates for pharmaceuticals & other organic chemicals; manufacture of glycerol & acrolein; military poison gas; herbicide | Koppers Co., Inc. -<br>Organic Materials Div.<br>Marathon Oil Co.<br>PMC Corp. - Chem. Group -<br>Indust. Chem. Div.<br>Shell Chem. Co. -<br>Base Chems. | Robinson, Ill.<br>Rayport, Tex.<br>Deer Park, Tex.                                                | -<br>-<br>-                                       | -                                                                           |
| Allyl chloride                 | Preparation of allyl alcohol & other derivatives; thermo-setting resins for varnishes, plastics, adhesives; intermediates for pharmaceuticals, glycerol & insecticides   | Dow Chem. U.S.A.<br>Shell Chem. Co. -<br>Base Chems.                                                                                                     | Freeport, Tex.<br>Deer Park, Tex.<br>Norco, La.                                                   | -<br>-<br>-                                       | -                                                                           |
| Amino-benzoic acid<br>(m,o,p)  | Dyes; drugs; perfumes & pharmaceuticals; dye intermediates                                                                                                               | Bofors Indust., Inc.<br>Salisbury Labs.<br>The Sherwin-Williams Co. - Sherwin-Williams Chems. Div.                                                       | Linden, N.J.<br>Charles City, Iowa<br>Wilmington, N.C.<br>Wilmington, N.C.<br>St. Bernard, Calif. | -<br>-<br>-<br>-                                  | -                                                                           |

Table A-1. (Continued)

| Chemical                                            | Usage <sup>1</sup>                                                                                                                                                                                                                            | Manufacturers <sup>(2,3)</sup>                                                                                                                                                                                                          | Location(s) <sup>(2,3)</sup>                                                                                                                                | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Amino-<br>benzoic<br>acid<br>(m.o.p)<br>(continued) |                                                                                                                                                                                                                                               | Bofors Indust., Inc.<br>Northern Pine Chems., Inc.<br>Salisbury Labs.<br>Warner-Lambert Co. -<br>Farke, Davis & Co.,<br>subsidi.                                                                                                        | Linden, N.J.<br>Franklin, N.J.<br>Wilmington, N.C.<br>Holland, Mich.                                                                                        | -<br>-<br>-<br>-                            | -                                                                           |
| Amino-<br>ethyl-<br>ethanol-<br>amine               | Textile finishing<br>compounds; anti-fuming<br>agents; dyestuffs;<br>cationic surfactants;<br>resins, rubber products,<br>insecticides, & certain<br>medicinals                                                                               | Dow Chem. U.S.A.<br>Hodag Chem. Corp.<br>Texaco Inc. - Jefferson<br>Chem. Co., Inc., subsid.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                         | Freeport, Tex.<br>Skokie, Ill.<br>Conroe, Tex.<br>Institute & South<br>Charleston, W. Va.<br>Texas City, Tex.                                               | -<br>-<br>-<br>-<br>-                       | -                                                                           |
| Amyl<br>acetates                                    | Solvent for lacquers &<br>paints; extractions;<br>penicillin; photographic<br>film; leather polishes;<br>nail polish; warming<br>odor; flavoring agent;<br>printing & finishing<br>fabrics; solvent for<br>phosphors in fluorescent<br>lamps. | Commercial Solvents Corp.<br>Publicker Indust. Inc.<br>Institute & South<br>Charleston, W. Va.                                                                                                                                          | Terre Haute, Inc.<br>Philadelphia, Pa.                                                                                                                      | -<br>-                                      | 5.4 (12) -1973                                                              |
| Amyl<br>alcohols<br>(9 isomers)                     | Solvent; raw material for<br>pharmaceutical prepara-<br>tions; organic synthetics;<br>lubricants; plasticizers;<br>additives; perfumes;<br>paints; flotation agent;<br>medicine                                                               | Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Eastman Kodak Co. -<br>Eastman Organic Chem.<br>Fennell Corp., Chem. Div.<br>The Area Labs., Inc.<br>Fennell Corp. - Chem.<br>Div.<br>Virginia Chems. Inc. -<br>Indust. Chems. Dept. | Institute & South<br>Charleston, W. Va.<br>Texas City, Tex.<br>Rochester, N.Y.<br>Wyandotte, Mich.<br>Milford, Conn.<br>Wyandotte, Mich.<br>Portsmouth, Va. | -<br>-<br>-<br>-<br>-<br>-                  | -                                                                           |
| Amyl-<br>amine                                      | Chemical intermediate;<br>dyestuffs; rubber chemi-<br>cals; insecticides;<br>synthetic detergents;<br>flotation agents; cor-<br>rosion inhibitors; solvent;<br>gasoline additive;<br>pharmaceuticals                                          |                                                                                                                                                                                                                                         |                                                                                                                                                             |                                             |                                                                             |



Table A-1. (Continued)

| Chemical                      | Usage <sup>1</sup>                                                                                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                     | Location(s) <sup>2,3</sup>                                                                                                                            | 1975 capacity <sup>2</sup><br>MM KG (MM lb)                                                          | Total <sup>4,5</sup><br>production<br>MM KG (MM lb)<br>for year of estimate |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Anil<br>chloride              | Synthesis of other anil<br>compounds; solvent;<br>rotogravure ink vehicles;<br>soil fumigation                                                                                                                                                                       | Columbia Organic Chem.<br>Co.<br>Eastman Kodak - East-<br>man Organic Chem.<br>Fennwalt Corp.                                                                                                                                                                      | Columbia, S. C.<br>Rochester, N. Y.<br>Greens Bayou, Tex.                                                                                             | -<br>-<br>-                                                                                          | -                                                                           |
| Anil<br>mercaptans            | Synthesis of organic sul-<br>fur compounds; chief<br>constituent of odorant<br>used in gas lines to<br>locate leaks                                                                                                                                                  | Fennwalt Corp.                                                                                                                                                                                                                                                     | Greens Bayou, Tex.                                                                                                                                    | -                                                                                                    | -                                                                           |
| Anil<br>phenol                | Dispersing & mixing<br>agent for paint pastes;<br>antiskinning agent for<br>paint, varnish, & elec-<br>tronic enamels; organic<br>synthesis; Manufacture<br>of oil-soluble resins;<br>plasticizer; germicide;<br>fumigant                                            | Fennwalt Corp. -<br>Chem. Div.<br>Productol Chem. Co.                                                                                                                                                                                                              | Wyandotte, Mich<br>Santa Fe Springs,<br>Calif.                                                                                                        | -<br>-                                                                                               | -                                                                           |
| Aniline                       | Rubber accelerators &<br>antioxidants; dyes &<br>intermediates; photo-<br>graphic chemicals<br>(hydroquinone); iso-<br>cyanates for urethane<br>foams; pharmaceuticals;<br>explosives; petroleum<br>refining; diphenylamine;<br>phenolics; herbicides,<br>fungicides | American Cyanamid Co. -<br>Organic Chem. Div.<br>E. I. du Pont de<br>Nemours & Co. Inc.<br>Eastman Chem. Dept.<br>Indust. Chem. Dept.<br>First Mississippi Corp.<br>First Chem. Corp., subsid.<br>Murray Chem. Corp. -<br>Indust. Chem. Div.<br>Rubicon Chem. Inc. | Bound Brook, N. J.<br>Willow Island, W. Va.<br>Beaumont, Tex.<br>Gibbstown, N. J.<br>Pascagoula, Miss.<br>New Martinsville,<br>W. Va.<br>Geismar, La. | 27.2 (60)<br>22.7 (50)<br>90.8 (200)<br>50 (130)<br>45.4 (100)<br>45.4 (100)<br>25 (55)<br>315 (700) | 237.3 (526.6) -1973                                                         |
| Aniline<br>hydro-<br>chloride | Dyes; intermediates;<br>dyeing & printing;<br>aniline black                                                                                                                                                                                                          | American Cyanamid Co. -<br>Organic Chem. Div.                                                                                                                                                                                                                      | Bound Brook, N. J.                                                                                                                                    | -                                                                                                    | -                                                                           |

Table A-1. (Continued)

| Chemical               | Usage <sup>1</sup>                                        | Manufacturer(s) <sup>2</sup>                                 | Location(s) <sup>2,3</sup> | 1975<br>Capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------|-----------------------------------------------------------|--------------------------------------------------------------|----------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Anilidine<br>Anilidine | Intermediate for azo dyes<br>& for quaternary azo<br>dyes | Aldrich Chem. Co., Inc.                                      | Wilmuakee, Wis.            | -                                              | -                                                                           |
|                        |                                                           | Eastman Kodak Co. -                                          | Rochester, N. Y.           | -                                              | -                                                                           |
|                        |                                                           | Eastman Organic Chem.                                        | Rock Haven, Va.            | -                                              | -                                                                           |
|                        |                                                           | American Color & Chem.<br>Corp.                              |                            |                                                |                                                                             |
|                        |                                                           | E. I. du Pont de Ne-<br>mours & Co., Inc.                    |                            |                                                |                                                                             |
|                        |                                                           | Organic Chem. Dept. -                                        |                            |                                                |                                                                             |
|                        |                                                           | Dyes & Chem. Div.                                            | Derpwater, N. J.           | -                                              | -                                                                           |
|                        |                                                           | Monsanto Co. - Monsanto<br>Indust. Chem. Co.                 | St. Louis, Mo.             | -                                              | -                                                                           |
|                        |                                                           | Salisbury Labs.                                              | Wilmington, N. C.          | -                                              | -                                                                           |
|                        |                                                           | Chem. Formulators, Inc.,<br>Chem. Div.                       | Nitro, W. Va.              | -                                              | -                                                                           |
| Anisole                | Solvent; perfumery;<br>vermicide; intermediate            | Continental Oil Co. -                                        | Newark, N. J.              | -                                              | -                                                                           |
|                        |                                                           | Conoco Chem. - Pitt-<br>Consol Chem.                         |                            |                                                |                                                                             |
|                        |                                                           | Eli Lilly & Co. -                                            | Lafayette, Inc.            | -                                              | -                                                                           |
|                        |                                                           | Tippecanoe Labs.                                             | Stifton, N. J.             | -                                              | -                                                                           |
|                        |                                                           | Givaudan Corp. - Chem.<br>Div.                               |                            |                                                |                                                                             |
|                        |                                                           | Salisbury Labs.                                              | Wilmington, N. C.          | -                                              | -                                                                           |
|                        |                                                           | The Sherwin-Williams<br>Co. - Sherwin-Williams<br>Chem. Div. | St. Bernard, Ohio          | -                                              | -                                                                           |
|                        |                                                           | American Cyanamid Co. -<br>Organic Chem. Div.                | Boundbrook, N. Y.          | -                                              | -                                                                           |
|                        |                                                           | E. I. du Pont de Ne-<br>mours & Co. - Organic<br>Chem. Dept. | Wilmington, Del.           | -                                              | -                                                                           |
|                        |                                                           | GAP Corporation                                              | Linden, N. J.              | -                                              | -                                                                           |
| Anthranilic<br>acid    | Dyes; drugs; perfumes<br>& pharmaceuticals                | Sterling Drug Inc. -                                         | Rensselaer, N. Y.          | -                                              | -                                                                           |

Table A-1. (Continued)

| Chemical     | Usage <sup>1</sup>                                                                                                                                                                                                                                                                      | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                  | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                                                                                       | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Benzaldehyde | Organic synthesis (especially of dyes & dye intermediates); solvent for oils, resins, cellulose acetate & nitrate; plasticizers; compounds; synthetic perfumes; manufacture of cinnamic acid, benzoic acid; pharmaceuticals & soaps; photographic chemicals; baking chemicals; medicine | Alco Standard Corp. -<br>Monsie Chem. Co., div.<br>Kalamazoo Chem. Inc.<br>Northwest Indust.,<br>Inc. - Velsicol Chem.<br>Corp., subsid.<br>Stauffer Chem. Co. -<br>Specialty Chem. Div.<br>Tenneco Inc. - Organics<br>& Polymers Div.<br>Universal Oil Products<br>Corp. - Chem. & Plastics<br>Group, Chem. Div.<br>Aceto Chem. Co., Inc. -<br>Arymac, Inc., subsid.<br>Guardian Chem. Corp. -<br>Eastern Chem. Div.<br>Allied Chem. Corp. -<br>Union Texas Petroleum<br>Div.<br>Amaral Hess Corp. -<br>Hess Oil Virgin Islands<br>Corp., subsid.<br>American Petrofina, Inc. -<br>American Petrofina Co.<br>of Texas, subsid.<br>Cosden Oil & Chem.<br>Co., subsid.<br>Armco Steel Corp.<br>Ashland Oil, Inc. -<br>Ashland Chem. Co., div.<br>Petrochems. Div.<br>Atlantic Richfield Co. -<br>ARCO Chem. Co., div. | Eddystone, Pa.<br>Kalamazoo, Mich.<br>Chattanooga, Tenn.<br>Edison, N. J.<br>Ponds, N. J.<br>East Rutherford,<br>N. J.<br>Carlstadt, N. J.<br>Hauptauge, N. Y.<br>Winnic, Tex.<br>St. Croix,<br>Virgin Islands<br>Port Arthur, Tex.<br>Big Spring, Tex.<br>Houston, Tex.<br>Middleton, Ohio<br>Ashland, Ky.<br>North Tonawanda,<br>N. Y.<br>Houston, Tex.<br>Wilmington, Del.<br>Pethlehem, Pa.<br>Lackawanna, N. Y.<br>Sparrows Point, Md. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>10 (22)<br>50 (110.2)<br>50 (110.2)<br>100 (220.5)<br>3 (6.6)<br>6.7 (14.7)<br>146.8 (323.4)<br>3.3 (7.3)<br>22 (48.4)<br>50 (110.2) | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>3694 (8136) - 1971             |
| Benzamide    | Organic synthesis                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                   |                                                                             |
| Benzene      | Styrene; phenol; synthetic detergents; cyclohexane for Nylon; aniline; DDT; maleic anhydride; dichlorobenzene; benzene hexachloride; nitrobenzene; diphenyl; insecticides; fumigants; solvent; paint removers; rubber cement; antiknock gasoline                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                   |                                                                             |

Table A-1. (Continued)

| Chemical<br>(Cont'd) | Usage <sup>1</sup><br>(see previous page) | Manufacturer(s) <sup>2,3</sup>                                                         | Location(s) <sup>2,3</sup> | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(see previous page) |
|----------------------|-------------------------------------------|----------------------------------------------------------------------------------------|----------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Benzene<br>(Cont'd)  | (see previous page)                       | CF&I Steel Corp.                                                                       | Pueblo, Colo.              | 10 (22)                                        | (see previous page)                                                                                |
|                      |                                           | The Charter Co., Charter Oil Co., subd.                                                | Houston, Tex.              | 16.7(36.7)                                     |                                                                                                    |
|                      |                                           | Cities Service Co., Inc. - North American Petroleum Group                              | Lake Charles, La.          | 83.4(183.7)                                    |                                                                                                    |
|                      |                                           | Coastal States Gas Corp.                                                               | Corpus Christi, Tex.       | 233.6(514.5)                                   |                                                                                                    |
|                      |                                           | Coastal States Marketing, Inc., subd.                                                  | Pennelias, P. R.           | 617 (1359.7)                                   |                                                                                                    |
|                      |                                           | Commonwealth Oil Refining Co., Inc. - Commonwealth Petroleum, Inc., subd.              | Pasadena, Tex.             | 66.7(147)                                      |                                                                                                    |
|                      |                                           | Crown Central Petroleum Corp.                                                          | Ray City, Mich.            | 100.1(220.5)                                   |                                                                                                    |
|                      |                                           | Dow Chem. U.S.A.                                                                       | Freeport, Tex.             | 133.5(294)                                     |                                                                                                    |
|                      |                                           | Exxon Corp. - Exxon Chem. Co., div. - Exxon Chem. Co. U.S.A.                           | Baton Rouge, La.           | 240.2(529.2)                                   |                                                                                                    |
|                      |                                           | Gulf Oil Corp. - Gulf Oil Chem. Co., div. - Petrochem. Div.                            | Raytown, Tex.              | 206.9(455.7)                                   |                                                                                                    |
|                      |                                           | Interlake, Inc. - Jones & Laughlin Indust., Inc. - Jones & Laughlin Steel Corp., subd. | Alliance, La.              | 233.6(514.5)                                   |                                                                                                    |
|                      |                                           | Kerr-McGee Corp. - Southern Refining Co., Inc., subd.                                  | Philadelphia, Pa.          | 110 (242.5)                                    |                                                                                                    |
|                      |                                           | Marathon Oil Co.                                                                       | Port Arthur, Tex.          | 126.8(279.3)                                   |                                                                                                    |
|                      |                                           | The Mead Corp. - Metals & Minerals Div.                                                | Toledo, Ohio               | 3.3(7.3)                                       |                                                                                                    |
|                      |                                           |                                                                                        | Alliquippa, Pa.            | 33.4(73.5)                                     |                                                                                                    |
|                      |                                           |                                                                                        | Corpus Christi, Tex.       | 26.7(58.8)                                     |                                                                                                    |
|                      |                                           |                                                                                        | Texas City, Tex.           | 20 (44.1)                                      |                                                                                                    |
|                      |                                           |                                                                                        | Woodward, Ala.             | 4.7(10.3)                                      |                                                                                                    |

Table A-1. (Continued)

| Chemical<br>(continued) | Usage <sup>1</sup><br>(see 2nd prev. page) | Manufacturer(s) <sup>2,3</sup>                                   | Location(s) <sup>2,3</sup>          | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(see 2nd previous page) |
|-------------------------|--------------------------------------------|------------------------------------------------------------------|-------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Benzene<br>(continued)  |                                            |                                                                  |                                     |                                                |                                                                                                        |
|                         |                                            | Mobil Oil Corp. - Mobil<br>Chem. Co., div. -<br>Petrochems. Div. | Beaumont, Tex.                      | 200 (441)                                      |                                                                                                        |
|                         |                                            | Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.         | Chocolate Bayou,<br>Tex.            | 250.2(551.2)                                   |                                                                                                        |
|                         |                                            | Northwest Indust., Inc.<br>Lone Star Steel Co.,<br>subsidi.      | Lone Star, Tex.                     | 4 (8.8)                                        |                                                                                                        |
|                         |                                            | Penzoil Co. - Atlas<br>Processing Co., subsidi.                  | Shreveport, La.                     | 40 (88.2)                                      |                                                                                                        |
|                         |                                            | Phillips Petroleum Co.                                           | Sweeny, Tex.                        | 73.2(161.7)                                    |                                                                                                        |
|                         |                                            | Phillips Puerto Rico<br>Core Inc., subsidi.                      | Guayama, P. R.                      | 367 (808.5)                                    |                                                                                                        |
|                         |                                            | Republic Steel Corp. -<br>Iron & Chem. Div.                      | Youngstown, Ohio                    | 13.3(29.4)                                     |                                                                                                        |
|                         |                                            | Shell Chem. Co. - Base<br>Chem.                                  | Deer Park, Tex.<br>Odessa, Tex.     | 250.2(551.2)                                   |                                                                                                        |
|                         |                                            | Skelly Oil Co.                                                   | Wilmington, Calif.                  | 16.7(36.7)                                     |                                                                                                        |
|                         |                                            | Standard Oil Co. of<br>California                                | Wood River, Ill.                    | 66.7(147)                                      |                                                                                                        |
|                         |                                            | Standard Oil Co. (Ind.)                                          | El Dorado, Kans.                    | 131.5(294)                                     |                                                                                                        |
|                         |                                            | Amoco Oil Co., subsidi.                                          | El Segundo, Calif.                  | 46.7(102.9)                                    |                                                                                                        |
|                         |                                            | Sun Oil Co. - Sun Oil<br>Co. of Pa.                              | Texas City, Tex.                    | 50 (110.2)                                     |                                                                                                        |
|                         |                                            | Suntide Refining Co.,<br>subsidi.                                | Marcus Hook, Pa.                    | 80 (176.4)                                     |                                                                                                        |
|                         |                                            | Tenneco Inc. - Tenneco<br>Oil Co., div.                          | Corpus Christi,<br>Tex.             | 100 (220.5)                                    |                                                                                                        |
|                         |                                            | Union Carbide Corp. -<br>Chem. & Plastics Div.                   | Chalmette, La.<br>Port Arthur, Tex. | 33.4(73.5)                                     |                                                                                                        |
|                         |                                            | Union Oil Co. of Calif.                                          | Westville, N. J.                    | 150.1(330.7)                                   |                                                                                                        |
|                         |                                            | Union Pacific Corp. -<br>Champion Petroleum Co.,<br>subsidi.     | Taft, La.                           | 116.8(257.2)                                   |                                                                                                        |
|                         |                                            | United States Steel<br>Corp. - USS Chem., div.                   | Reaumont, Tex.<br>Lemont, Ill.      | 166.8(367.5)                                   |                                                                                                        |
|                         |                                            |                                                                  | Corpus Christi,<br>Tex.             | 40 (88.2)                                      |                                                                                                        |
|                         |                                            |                                                                  | Clairton, Pa.                       | 110.1(242.5)                                   |                                                                                                        |
|                         |                                            |                                                                  | Geneva, Utah                        | 38.3(83.5)                                     |                                                                                                        |
|                         |                                            |                                                                  |                                     | 133.5(294)                                     |                                                                                                        |
|                         |                                            |                                                                  |                                     | 13.3(29.4)                                     |                                                                                                        |
|                         |                                            |                                                                  |                                     | Total <sup>6</sup>                             | 5816.2(12811)                                                                                          |

Table A-1. (Continued)

| Chemical                       | Usage <sup>1</sup>                                                                                                                                                                 | Manufacturer(s) <sup>2,3</sup>                                                                                                                                        | Location(s) <sup>2,3</sup>                                                                   | 1975<br>capacity <sup>2</sup><br>MW kg (MW lb) | Total <sup>4,5</sup><br>production<br>MW kg (MW lb)<br>for year of estimate |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Benzene-<br>sulfonic<br>acid   | Phenol; resorcinol;<br>organic synthesis;<br>catalyst                                                                                                                              | Nease Chem. Co., Inc.<br>Stauffer Chem. Co.,<br>Agricultural Chem. Div.<br>Jim Walter Corp. - U.S.<br>Pipe & Foundry Co.,<br>subsidi., Chem. Div.                     | State College, Pa.<br>Henderson, Nev.<br>Birmingham, Ala.                                    | -<br>-<br>-                                    | -                                                                           |
| Benzenedi-<br>sulfonic<br>acid | -                                                                                                                                                                                  | Koppers Co., Inc. -<br>Organic Materials Div.<br>Jim Walter Corp. - U.S.<br>Pipe & Foundry Co.,<br>subsidi., Chem. Div.<br>Napp Chem. Inc.                            | Petrolia, Pa.<br>Birmingham, Ala.<br>Lodi, N. J.                                             | -<br>-<br>-                                    | -                                                                           |
| Benzil                         | Organic synthesis;<br>insecticide                                                                                                                                                  | Stauffer Chem. Co. -<br>Specialty Chem. Div.                                                                                                                          | Edison, N. J.                                                                                | -                                              | -                                                                           |
| Benzilic<br>acid               | Chemical<br>intermediate                                                                                                                                                           | Kalama Chem., Inc.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.<br>Northwest Indust.,<br>Inc. - Velsicol Chem.<br>Corp., subsidi.<br>Pfizer Inc. - Chems.<br>Div. | Kalama, Wash.<br>St. Louis, Mo.<br>Beaumont, Tex.<br>Chattanooga, Tenn.<br>Terre Haute, Ind. | 54.5 (120)<br>4.5 (10)<br>22.7 (50)<br>2.7 (6) | 36.8 (81) -1974                                                             |
| Benzoin                        | Organic synthesis;<br>intermediate; phar-<br>macological                                                                                                                           | Tenneco Inc. - Tenneco<br>Chems., Inc., Organics<br>& Polymers Div.<br>Napp Chem., Inc.<br>Stauffer Chem. Co. -<br>Specialty Chem. Div.                               | Garfield, N. J.<br>Lodi, N. J.<br>Edison, N. J.                                              | 5.4 (12)<br>-<br>-                             | Total =<br>117.1 (258)                                                      |
| Benzonitrile                   | Manufacture of benzo-<br>guanidine; intermediate<br>solvent for nitride;<br>rubber, specialty lac-<br>quers, and many resins &<br>polymers, & for many<br>anhydrous metallic salts | Northwest Indust. Inc. -<br>Velsicol Chem. Corp.,<br>subsidi.                                                                                                         | Chattanooga, Tenn.                                                                           | -                                              | -                                                                           |

Table A-1. (Continued)

| Chemical          | Usage <sup>1</sup>                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                           | 1975 capacity, <sup>2</sup><br>MM kg (MM lb)        | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|
| Benzo-phenone     | Organic synthesis; perfumery; odor fixative; ultraviolet absorbers; flavoring; polymerization inhibitor for styrene | Aceto Chem. Co., Inc.-<br>Araynco, Inc., subsid.<br>GAP Corp. - Chem. Div.<br>Norda Inc.<br>Orbia Products Corp.<br>Universal Oil Products Co. - Chems. & plastics Group - Chem. Div.<br>Warner-Lambert Co. -<br>Parke, Davis & Co.,<br>subsid.<br>Eastman Kodak Co. -<br>Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Frank Enterprises<br>Northwest Indust., Inc.<br>Velsicol Chem. Corp.,<br>subsid.<br>Occidental Petroleum Corp., Hooker Chem. Corp., subsid - Hooker<br>Chems. & Plastics Corp.,<br>subsid. - Electrochemical & Specialty Chems. Div.<br>Tenneco Inc. - Tenneco Chems., Inc. - Organics & Polymers Div. | Carlstadt, N. J.<br>Rensselaer, N. Y.<br>Rochester, N. J.<br>East Hanover, N. J.<br>Newark, N. J.<br>East Rutherford, N. J.<br>Holland, Michigan<br>Kingsport, Tenn.<br>Columbus, Ohio<br>Chattanooga, Tenn.<br>Niagara Falls, N. Y.<br>Fords, N. J. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-                         |
| Benzo-quinone     | Manufacture of dyes & hydroquinone                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                      |                                                     |                                                                             |
| Benzo-trichloride | Synthetic dyes; organic synthesis                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                      |                                                     |                                                                             |

Table A-1. (Continued)

| <u>Chemical</u>  | <u>Usage<sup>1</sup></u>                                                                | <u>Manufacturer(s)<sup>2,3</sup></u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <u>Location(s)<sup>2,3</sup></u>                                                                                                                                                                                                                                                                       | 1975<br>capacity,<br>MM kg (MM lb)                                                | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate       |
|------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Benzoyl chloride | Medicine; intermediate for production of benzyl groups; intermediate for other organics | Northwest Indust., Inc. - Veisicol Chem. Corp., subsid.<br>Occidental Petroleum Corp.; Hooker Chem., Ltd.; Hooker Chem., Ltd. & Veisicol Chem., Ltd. - Electrochemical & Specialty Chems. Div.<br>Stauffer Chem. Co. - Specialty Chem. Div.<br>Tenneco Chems., Inc. - Tenneco Chems., Inc.; Organics & Polymers Div.<br>Alco Standard Corp. - Monroe Chem. Co., div.<br>Cloray NJ Corp.<br>Glavanian Corp. - Chems. Div.<br>Northwest Indust., Inc. - Veisicol Chem. Corp., subsid.<br>Ortis Products Corp.<br>Stauffer Chem. Co. - Specialty Chem. Div.<br>Tenneco Inc. - Tenneco Chems., Inc.; Organics & Polymers Div.<br>Universal Oil Products Co. - Chems. & Plastics Group - Chem. Div.<br>Aceto Chem. Co., Inc. - Arsyco, Inc., subsid.<br>Miles Labs., Inc. - Summer Div.<br>Univacal, Inc. - Univacal Chem., div. | Chattanooga, Tenn.<br><br>Niagara Falls,<br><br><br>Edison, N. J.<br>Pords, N. J.<br><br>Eddystone, Pa.<br>Newark, N. J.<br>Clifton, N. J.<br>Chattanooga, Tenn.<br>Newark, N. J.<br>Edison, N. J.<br>Pords, N. J.<br>East Rutherford, N. J.<br>Carlstadt, N. J.<br>Zeeland, Mich.<br>Naugatuck, Conn. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- |
| Benzylamine      | Chemical intermediate for dyes, pharmaceuticals, & polymers                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                        |                                                                                   |                                                                                   |



Table A-1. (Continued)

| Chemical          | Usage                                                                                                                                                                                                                                     | Manufacturer(s)                                                         | Location(s)                                            | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>1,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Benzyl benzoate   | Fixative & solvent for<br>mask in perfumes &<br>flavors; medicine<br>(external); plasticizer;<br>miticide                                                                                                                                 | Monsanto Co. - Monsanto<br>Flavor/Essence, Inc.                         | St. Louis, Mo.                                         | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Monsanto Indust. Chems.<br>Co.                                          | St. Louis, Mo.                                         | -                                           | -                                                                           |
| Benzyl chloride   | Dyes; intermediates;<br>resin compounds; syn-<br>thetic detergents;<br>fuels; pharmaceuticals;<br>manufacture of photo-<br>graphic developer;<br>gasoline gum inhibi-<br>tors; penicillin<br>precursors; quaternary<br>ammonium compounds | Northwest Indust., Inc. -<br>Veisicol Chem. Corp.,<br>subsidi.          | Chattanooga, Tenn.                                     | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Pfizer Inc. -<br>Chems. Div.                                            | Greenboro, N. C.                                       | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Universal Oil Products<br>Co. - Chems. & Plastics<br>Group - Chem. Div. | East Rutherford,<br>N. J.                              | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | W. R. Grace & Co. -<br>Hatch Group - Hatch<br>Chem. Div.                | Fords, N. J.                                           | 6.8 (15)                                    | 40.9 (90) -1971                                                             |
|                   |                                                                                                                                                                                                                                           | Monsanto Co. - Monsanto<br>Indust. Chems. Co.                           | Bridgeport, N. J.                                      | 34 (75)                                     | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Northwest Indust., Inc.<br>Veisicol Chem. Corp.,<br>subsidi.            | Chattanooga, Tenn.                                     | 4.5 (10)                                    | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Stauffer Chem. Co. -<br>Specialty Chem. Div.                            | Edison, N. J.                                          | 5 (11)                                      | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>& Polymers Div.    | Fords, N. J.                                           | 3.2 (7)                                     | -                                                                           |
|                   |                                                                                                                                                                                                                                           | OAF Corp. - Chem. Div.                                                  | Rensselaer, N. Y.                                      | Total =<br>536 - (118)                      | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>& Polymers Div.    | Great Meadows,<br>N. J.                                | -                                           | -                                                                           |
| Benzyl dichloride | Dyes                                                                                                                                                                                                                                      | Bethlehem Steel Corp.<br>Chemol, Inc.                                   | Sparrows Point, Md.                                    | -                                           | 2.3 (5) -1971                                                               |
| Biphenyl          | Organic synthesis; heat<br>transfer agent; fungi-<br>cides; dyeing assistant<br>for polyester                                                                                                                                             | Dow Chem. U.S.A.                                                        | Greensboro, N. C.                                      | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Monsanto Co. - Monsanto<br>Indust. Chems. Co.                           | Bay City, Mich.                                        | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Pilot Chem. Co. - Pilot<br>Indust. of Texas, subsidi.                   | Freeport, Tex.                                         | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Sybron Corp. - The                                                      | Anniston, Ala.                                         | -                                           | -                                                                           |
|                   |                                                                                                                                                                                                                                           | Tanatek Chem. Co., div.<br>Woonsocket Color & Chem.<br>Co.              | Houston, Tex.<br>Lyndhurst, N. J.<br>Woonsocket, R. I. | -                                           | -                                                                           |

Table A-1. (Continued)

| Chemical                   | Usage <sup>1</sup>                                                                                                                                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                               | Location(s) <sup>2,3</sup>                                                                                                     | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                                             | Totals <sup>3,4</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Bisphenol A                | Epoxy, polycarbonate, phenolic, & polysulfone resins                                                                                                                                                                                | Dow Chem. U.S.A.<br>Gen. Electric Co. -<br>Plastics Business Div. -<br>Engineering Plastics<br>Product Dept.<br>Shell Chem. Co. -<br>Polymers & Detergent<br>Products<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>Union Carbide Caribe,<br>Inc., subsid.                                                                            | Freeport, Tex.<br>Mount Vernon, Ind.<br>Deer Park, Tex.<br>Marietta, Ohio<br>Peneelas, P. R.<br>Total =<br>196.1 (432)         | 45.4 (100)<br>32.7 (72)<br>68 (150)<br>18.2 (40)<br>31.8 (70)                              | 145.1 (319.7)-1973                                                           |
| Bromo-<br>benzene          | Solvent; motor fuels;<br>top-cylinder com-<br>pounds; crystallizing<br>solvent; organic<br>synthesis                                                                                                                                | Dow Chem. U.S.A.                                                                                                                                                                                                                                                                                                                             | Midland, Mich.                                                                                                                 | -                                                                                          | -                                                                            |
| Bromo-<br>naphtha-<br>lene | Organic synthesis;<br>microscopy;<br>refractometry                                                                                                                                                                                  | Eastman Kodak Co. -<br>Eastman Organic Chem.<br>Guardian Chem. Corp. -<br>Eastern Chem. Div.<br>R.S.A. Corp.                                                                                                                                                                                                                                 | Rochester, N. Y.<br>Hauppauge, N. Y.<br>Ardsley, N. Y.                                                                         | -<br>-<br>-                                                                                | -                                                                            |
| Eutadiene                  | Principally in sty-<br>rene-butadiene rubber,<br>& to a lesser degree in<br>polybutadiene and<br>nitrile elastomers;<br>as the starting material<br>for neoprene (Nylon<br>66); in latex paints;<br>resins; organic<br>intermediate | Atlantic Richfield Co. -<br>ARCO Chem. Co., div.<br>Copolymer Rubber &<br>Chem. Corp.<br>Dow Chem. U.S.A.<br>El Paso Natural Gas Co. -<br>El Paso Products Co.,<br>subsid.<br>Exxon Corp. - Exxon Chem.<br>Co., U.S.A. - Exxon Chem.<br>Co., div.<br>The Firestone Tire & Rub-<br>ber Co. Firestone<br>Synthetic Rubber & Latex<br>Co., div. | Channelview, Tex.<br>Baton Rouge, La.<br>Bay City, Mich.<br>Freeport, Tex.<br>Odessa, Tex.<br>Baton Rouge, La.<br>Orange, Tex. | 127 (280)<br>58.1 (128)<br>10.9 (24)<br>39 (86)<br>90.8 (200)<br>154.4 (340)<br>99.9 (220) | 1663 (3662.9)-1973                                                           |

Table A-1. (Continued)

| Chemical<br>Butadiene<br>(continued) | Usage <sup>1</sup><br>(see previous page) | Manufacturer(s) <sup>2,3</sup>                                                   | Location(s) <sup>2,3</sup>          | 1975<br>capacity <sup>4</sup><br>MM kg (MM lb) | Total <sup>5,6</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(see previous page) |
|--------------------------------------|-------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------|
|                                      |                                           | Getty Oil Co.                                                                    | Delaware City,<br>Del.              | 9.1 (20)                                       |                                                                                                    |
|                                      |                                           | Mobil Oil Corp. - Mobil<br>Chem. Co., div. -<br>Petrochems. Div.                 | Beaumont, Tex.                      | 36.3 (80)                                      |                                                                                                    |
|                                      |                                           | Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.                         | Chocolate Bayou                     | 54.5 (120)                                     |                                                                                                    |
|                                      |                                           | Neches Butane Products<br>Co.                                                    | Port Neches, Tex.                   | 290.6 (640)                                    |                                                                                                    |
|                                      |                                           | Northern Natural Gas Co.<br>Northern Petrochem Co.,<br>subsidiary, Polymers Div. | Morris, Ill.                        | 29.5 (65)                                      |                                                                                                    |
|                                      |                                           | Petro-Tex Chem. Corp. -<br>Petro-Tex Chem. Co.,<br>subsidiary                    | Houston, Tex.                       | 440.5 (900)                                    |                                                                                                    |
|                                      |                                           | Phillips Petroleum Co. -<br>Petrochem. & Supply Div.                             | Phillips, Tex.                      | 131.7 (290)                                    |                                                                                                    |
|                                      |                                           | Puerto Rico Olefins Co.                                                          | Penuelas, P. R.                     | 90.8 (200)                                     |                                                                                                    |
|                                      |                                           | Shell Chem. Co. - Base<br>Chems.                                                 | Deer Park, Tex.                     | 120.3 (265)                                    |                                                                                                    |
|                                      |                                           | Standard Oil Co. (Ind.) -<br>Amoco Chems. Corp., sub-<br>sidiary                 | Chocolate Bayou,<br>La.             | 40.9 (90)                                      |                                                                                                    |
|                                      |                                           | Union Carbide Corp. -<br>Chems. & Plastics Div.                                  | Seadrift, Tex.<br>Taft, La.         | 20.4 (45)<br>40.9 (90)                         |                                                                                                    |
|                                      |                                           | Union Carbide Carbide, Inc.<br>Subsidiary                                        | Texas City, Tex.<br>Penuelas, P. R. | 20.4 (45)<br>70.4 (155)                        |                                                                                                    |
|                                      |                                           |                                                                                  |                                     | Total =                                        | 1,985.3 (4,373)                                                                                    |

Table A-1. (Continued)

| Chemical           | Usage <sup>1</sup>                                                                                                                                                                      | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                      | Location(s) <sup>2,3</sup>                                                                                                | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                           | Total <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------|
| n-Butyl acetate    | Solvent in production of lacquers, lacquer enamels; pyroxylin solutions; leather dressings; perfumes, flavoring extracts; solvent for natural gums & synthetic resins; degreasing agent | Celanese Corp. - Celanese Chem. Div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subid. - Tenn. Eastman Co., div.<br>Publicker Indust. Inc.<br>Union Carbide Corp. - Chem. & Plastics Div. | Bishop, Tex.<br>Kingsport, Tenn.<br>Philadelphia, Pa.<br>Institute & South Charleston, W. Va.<br>Texas City, Tex.         | 6.8 (15)<br>6.8 (15)<br>6.8 (15)<br>22.7 (50)<br>Total =<br>43.1 (95) | 43.4 (95.7) -1972                                                           |
| sec-Butyl acetate  | Solvent for nitro-cellulose; lacquers; thinners; nail enamels; celluloid products; artificial leather; leather finishes; plastic wood; washable wallpaper                               | Exxon Corp. - Exxon Chem. Co.<br>Hercules, Inc.<br>Shell Chem. Co. - Indust. Chems./Petrochems.<br>(See also - n-Butyl acetate)                                                                     | Baton Rouge, La.<br>Hattiesburg, Miss.<br>Deer Park, Tex.                                                                 | -<br>-<br>-                                                           | 43.4 (95.7) -1967                                                           |
| tert-Butyl acetate | Possible antiknock agent in gasoline                                                                                                                                                    | Exxon Corp. - Exxon Chem. Co.<br>(See also - n-Butyl acetate)                                                                                                                                       | Baton Rouge, La.                                                                                                          | -                                                                     | -                                                                           |
| n-Butyl acrylate   | Intermediate in organic synthesis; polymers & copolymers for solvent coatings, adhesives, paints, binders; emulsifier                                                                   | Celanese Corp. - Celanese Chem. Co., div.<br>Dow Radiische Co.<br>Rohm & Haas Co. - Rohm & Haas Texas Inc., subid.<br>Union Carbide Corp. - Chem. & Plastics Div.                                   | Clear Lake, Tex.<br>Pampa, Tex.<br>Freeport, Tex.<br>Deer Park, Tex.<br>Institute & South Charleston, W. Va.<br>Taft, La. | -<br>-<br>-<br>-<br>-                                                 | -                                                                           |

Table A-1. (Continued)

| Chemical           | Usage <sup>1</sup>                                                                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                  | Location(s) <sup>2,3</sup>                                                                                                                                                                                              | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                                                                    | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| n-Butyl alcohol    | Preparation of esters, especially butyl acetate; solvent for resins & coatings; plasticizers; dyeing assistant; hydraulic fluids; detergent formulations; dehydrating agent (by azeotropic distillation); intermediates; "butylated" melamine resins | Celanese Corp. - Celanese Chem. Co., div.<br>Continental Oil Co. - Conoco Chems.<br>Dow Badische Co.<br>Eastman Kodak Co. - Eastman Chem. Products Inc. - Eastman Chem. Co., div.<br>M. R. Grace & Co. - Natco Group - Natco Chem. Div.<br>Oxochem Enterprise<br>Publicker Indust. Inc.<br>Shell Chem. Co. - Base Chems.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Union Carbide Caribe, Inc., subsid. | Bay City, Tex.<br>Bishop, Tex.<br>Clear Lake, Tex.<br>Westlake, La.<br>Freeport, Tex.<br>Longview, Tex.<br>Ponds, N. J.<br>Peneulas, P. R.<br>Philadelphia, Pa.<br>Deer Park, Tex.<br>Seadrift, Tex.<br>Peneulas, P. R. | -<br>68.2 (150)<br>20.4 (45)<br>2.3 (5)<br>43.1 (95)<br>31.8 (70)<br>-<br>36.3 (80)<br>15.9 (35)<br>36.3 (80)<br>27.2 (60)<br>18.2 (40)<br>Total = 299.6 (660) | 235.4 (518.6) -1973                                                         |
| sec-Butyl alcohol  | Preparation of methyl ethyl ketone; solvent; organic synthesis                                                                                                                                                                                       | Celanese Chem. Co.<br>Exxon Corp. - Exxon Chem. Co.<br>Shell Chem. Co. - Indust. Chems./Petrochems.<br>Shell Chem. Co. - Indust. Chems./Petrochems.<br>Oxirane Chem. Co.                                                                                                                                                                                                                                        | Bay City, Tex.<br>Bishop, Tex.<br>Clear Lake, Tex.<br>Baton Rouge, La.<br>Deer Park, Tex.<br>Martinez, Calif.<br>Bayport, Tex.                                                                                          | -<br>-<br>-<br>-<br>-<br>-<br>-                                                                                                                                | 205.6 (453) -1973<br>508.5 (1120) -1973                                     |
| tert-Butyl alcohol | Alcohol denaturant                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                         |                                                                                                                                                                |                                                                             |

Table A-1. (Continued)

| Chemical           | Usage                                                                                                                                                                                                                                                                                                                                                                       | Manufacturer(s)                                                                                                                                                                                                                                                           | Location(s)                                                                                                                                                                          | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                              | Total <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| tert-Butyl-phenol  | Chemical intermediate for synthetic resins, plasticizers, surface-active agents, perfumes, & other products; a permissible antioxidant for aviation gasoline; plasticizer for cellulose acetate nitrate; oil soluble phenolic resins; pour-point depressors & emulsion breakers for petroleum oils & some plastics; synthetic lubricants; insecticides; industrial odorants | Dow Chem. U.S.A.<br>Ethyl Corp.<br>Productol Chem. Co.<br>Schenectady Chem., Inc.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                                                                                                         | Midland, Mich.<br>Orangeburg, S. C.<br>Santa Fe Springs, Calif.<br>Rotterdam Junction, N. Y.<br>Round Brook, N. J.                                                                   | -<br>-<br>-<br>-<br>-                                                                                                    | -                                                                           |
| tert-Butyl-toluene | Solvent; intermediate                                                                                                                                                                                                                                                                                                                                                       | Shell Chem. Co. - Base Chems.                                                                                                                                                                                                                                             | Martinez, Calif.                                                                                                                                                                     | -                                                                                                                        | -                                                                           |
| n-Butyl-aldehyde   | Polyvinyl butyral; butyrate plastics                                                                                                                                                                                                                                                                                                                                        | Celanese Corp. -<br>Celanese Chem. Co., div.<br>Eastman Kodak Co. -<br>Eastman Chem. Products, Inc., subsid. -<br>Texas Eastman Co., div.<br>Oxochem Enterprise<br>Shell Chem. Co. - Base Chems.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Union Carbide Caribe, | Bay City, Tex.<br>Bishop, N. M.<br>Freerport, Tex.<br>Longview, Tex.<br>Penulas, P. R.<br>Deer Park, Tex.<br>Institute & South Charleston, W. Va.<br>Searift, Tex.<br>Penulas, P. R. | -<br>136.2 (300)<br>227 (500)<br>158.9 (350)<br>111.2 (245)<br>-<br>68.1 (150)<br>136.3 (300)<br>Total =<br>837.6 (1845) | -<br>-<br>-<br>-                                                            |

Table A-1. (Continued)

| Chemical            | Use <sup>1</sup>                                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                      | Location(s) <sup>2,3</sup>                                                          | 1975 capacity <sup>2</sup><br>MM kg (MM lb)          | Total <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------------------------------------------------------|
| n-Butyric acid      | Synthesis of butyrate ester perfume & flavor ingredients; pharmaceuticals; disinfectant; emulsifying agents; sweetening gasolines | Celanese Corp. - Celanese Chem. Co., div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Union Carbide Corp. - Chems. & Plastics Div. | Pampa, Tex.<br>Eastman, Tenn.<br>Institute & South Charleston, W. Va.               | -<br>-<br>-                                          | -                                                                           |
| n-Butyric anhydride | Manufacture of butyrates; drugs; tanning agents                                                                                   | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Union Carbide Corp. - Chems. & Plastics Div.                                              | Kingsport, Tenn.<br>Institute & South Charleston, W. Va.<br>Longview, Tex.          | -<br>-<br>-                                          | -                                                                           |
| n-Butyronitrile     | Basic material in industrial, chemical & pharmaceutical intermediates & products; poultry medicines                               | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Lonza Inc.                                                                                | Mapleton, Ill.<br>South Charleston, W. Va.<br>Greens Bayou, Tex.                    | 91.7 (180)<br>4.5 (10)<br>27.2 (60)                  | 351.8 (775) -1972                                                           |
| Carbon disulfide    | Viscose rayon; cellophane; manufacture of carbon tetrachloride & flotation agents; veterinary medicine; solvent                   | PMC Corp. - Chem. Group - Indust. Chem. Div.<br>Pennwalt Corp. - Chem. Div.<br>PPG Indust., Inc. - Chem. Div. - Indust. Chem. Div.<br>Stauffer Chem. Co. - Indust. Chem. Div.       | Mapleton, Ill.<br>South Charleston, W. Va.<br>Greens Bayou, Tex.<br>Natrium, W. Va. | 91.7 (180)<br>4.5 (10)<br>27.2 (60)                  | 351.8 (775) -1972                                                           |
| Carbon tetrabromide | Organic synthesis                                                                                                                 | Great Lakes Chem. Corp.<br>Olin Corp. - Designed Products Div.                                                                                                                      | Delaware City, Del.<br>Le Moyne, Ala.<br>El Dorado, Ark.<br>Rochester, N. Y.        | 158.9 (350)<br>113.5 (250)<br>Total =<br>272.4 (600) | -                                                                           |

Table A-1. (Continued)

| Chemical                  | Usage <sup>1</sup>                                                                                                                                                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                            | Location(s) <sup>4,5</sup>                                                                                                                                                                      | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>5,6</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| n-Butyl-amine             | Intermediate for emulsifying agents; pharmaceuticals; insecticides; rubber chemicals; dyes; tanning agents                                                                                                                                          | Air Products & Chems.<br>Pennwalt Corp. - Chem. Div.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Va. Chems. Inc. - Indust. Chems. Dept.<br>Pennwalt Corp. - Chem. Div.<br>Va. Chems. Inc. - Indust. Chems. Dept.<br>Monsanto Co. - Monsanto Indust. Chems. Co.<br>Rohm & Haas Co. - Rohm & Haas Tex Inc., subsid.<br>Shell Chem. Co. - Ease Chems. | Pensacola, Fla.<br>Wyandotte, Mich.<br>Institute & South Charleston, W. Va.<br>Ft. Smith, Va.<br>Wyandotte, Mich.<br>Portsmouth, Va.<br>Texas City, Tex.<br>Deer Park, Tex.<br>Martinez, Calif. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-      | 1.82 (4)<br>-1973                                                           |
| sec-Butyl-amine           | -                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |                                                |                                                                             |
| tert-Butyl-amine          | Intermediate for rubber accelerators; insecticides; fungicides; dyestuffs; pharmaceuticals                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |                                                |                                                                             |
| p-tert-Butyl-benzoic acid | -                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |                                                |                                                                             |
| 1,3-Butylene glycol       | Polyesters; polyurethanes; surface active agents; plasticizers; humectant; coupling agent; solvent; food additive & flavoring                                                                                                                       | Celanese Corp. - Celanese Chem. Co., div.                                                                                                                                                                                                                                                                                                                 | Bishop, Tex.                                                                                                                                                                                    | -                                              | -                                                                           |
| Butylenes                 | Polymer & alkylate gasoline; polyketenes; butadiene; intermediate for C <sub>4</sub> & C <sub>5</sub> aldehydes, alcohols, & other derivatives; cross-linking agents; butadiene synthesis; synthesis of C <sub>4</sub> & C <sub>5</sub> derivatives | Dow Chem. U.S.A.<br>Gulf Oil Corp. - Gulf Oil Chems. Co., div. - Petrochems div.<br>Petro-Tex Chem. Corp. - Petro-Tex Chem. Co., subsid.                                                                                                                                                                                                                  | Bay City, Mich.<br>Freeport, Tex.<br>Cedar Bayou, Tex.<br>Houston, Tex.                                                                                                                         | -<br>-<br>-<br>-                               | 10,074 (22,190)-1967                                                        |



Table A-1. (Continued)

| Chemical             | Use <sup>1</sup>                                                                                                            | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                               | Location(s) <sup>3</sup>                                                                                                                                                                                                                      | 1975<br>Production <sup>2</sup><br>MM lb. (MM lb.)                                                                                                                 | Total 4-5<br>Production <sup>2</sup><br>MM lb. (MM lb.)<br>for year of estimate |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Carbon tetrachloride | Refrigerants & propellants; solvents; degreasing; dry cleaning; chlorinated organic compounds; production of semiconductors | Allied Chem. Corp. - Specialty Chem. Div.<br>Dow Chemical U.S.A.<br>E. I. du Pont de Nemours & Co., Inc. - Organic Chems. - Dept. Freon <sup>®</sup> - Products Div.<br>PMC Corp. - Chem. Group - Indust. Chem. Div.<br>Inland Chem. Corp.<br>Stauffer Chem. Co. - Indust. Chem. Div.<br>Vulcan Materials, Co. - Chems. Div. | Mountsville, N. Va.<br>Freeport, Tex.<br>Pittsburg, Ca.<br>Flaguette, La.<br>Corpus Christi, Tex.<br>South Charleston, W. Va.<br>Manati, P. R.<br>Le Moyne, Ala.<br>Louisville, Ky.<br>Niagara Falls, N. Y.<br>Geismar, La.<br>Wichita, Kans. | 3.6 (3)<br>50 (130)<br>26.4 (45)<br>45.8 (100)<br>-<br>136.2 (303)<br>-<br>90.8 (200)<br>31.8 (70)<br>68.1 (150)<br>15.9 (35)<br>13.2 (30)<br>Total = 716.4 (1578) | 458.3 (1009.4) -1971                                                            |

Table A-1.(Continued)

| Chemical          | Usage <sup>1</sup>                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                           | Location(s) <sup>2,3</sup>                                                                             | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                           | Totals <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Cellulose acetate | Acetate fibers; lacquers; protective coating solutions; photographic film, transparent sheeting, thermoplastic molding composition, cigarette filters, magnetic tapes, osmotic cell membrane | Celanese Corp. - Celanese Fibers Co., div.<br>E. I. du Pont de Nemours & Co., Inc. - Textile Fibers Dept.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn. Eastman Co., div.<br>FMC Corp. - Chem. Group - Fiber Div. | Narrows, Va.<br>Rock Hill, S. C.<br>Rome, Ga.<br>Waynesboro, Va.<br>Kingsport, Tenn.<br>Meadville, Pa. | 227 (500)<br>27.2(60)<br>156.6(345)<br>11.3(25)<br>Total = 422.2(930) | 209.8 (462.2) -1973                                                          |
| Chloranil         | Agricultural fungicide; dye intermediate; electrodes for pH measurements; vulcanizing agent                                                                                                  | -                                                                                                                                                                                                                                        | -                                                                                                      | -                                                                     | -                                                                            |
| Chloroacetic acid | Herbicide; intermediate in production of carbonyl compounds, ethyl chloroacetate, glycine, synthetic caffeine, sacrosine, thioglycolic acid, EDTA, 2,4-D, 2,4,5-T                            | Dow Chem. U.S.A. Hercules Inc. - Coating & Specialty Products Dept.<br>The Procter & Gamble Co. - The Buckeye Cellulose Corp., subsid.                                                                                                   | Midland, Mich.<br>Hopewell, Va.<br>Memphis, Tenn.                                                      | 20.4(45)<br>9.1(20)<br>1.4(3)<br>Total = 30.9 (68)                    | 29.1 (64.2) -1969                                                            |
| m-chloroaniline   | Intermediate for azo dyes & pigments; pharmaceuticals; insecticides; agricultural chemicals                                                                                                  | E. I. du Pont de Nemours & Co., Inc., Organic Chems. Dept. - Dyes & Chems. Div.<br>GAP Corp. - Chem. Div.                                                                                                                                | Deepwater, N. J.<br>Linden, N. J.                                                                      | -<br>-                                                                | -                                                                            |
| o-chloroaniline   | Dye intermediate; standards for colorimetric apparatus; manufacture of petroleum solvents & fungicides                                                                                       | E. I. du Pont de Nemours & Co., Inc. - Organic Chems. Dept. - Dyes & Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.                                                                                                           | Deepwater, N. J.<br>Luling, La.                                                                        | -<br>-                                                                | -                                                                            |

Table A-1. (Continued)

| Chemical            | Usage <sup>1</sup>                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Location(s) <sup>2,3</sup>                                      | 1975 capacity <sup>2</sup><br>MM KG (MM lb.) | Total <sup>5</sup><br>production<br>MM KG (MM lb.)<br>for year of estimate |
|---------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------|----------------------------------------------------------------------------|
| p-chloro-aniline    | Dye intermediate; pharmaceuticals; agricultural chemicals                                                    | E. I. du Pont de Nemours & Co., Inc., Organic Chems. Div. - Tyes & Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Deepwater, N. J.<br>Luling, La.                                 | -<br>-                                       | -<br>-                                                                     |
| Chloro-benzaldehyde | Intermediate in the preparation of triphenyl methane & related dyes; organic intermediate                    | Occidental Petroleum Corp. - Hooker Chem. Corp., subsid. - Hooker Chems. & Plastics Corp., subsid. - Electrochem. Div. & Specialty Chems. Div.<br>Tennessee Inc. - Tennessee Chems., Inc. - Organics & Polymers Div.<br>Allied Chem. Corp. - Indust. Chems. Div.<br>Dow Chem. U.S.A.<br>Monsanto Co. - Monsanto Indust. Chems. Co.<br>Montrose Chem. Corp. of California<br>Occidental Petroleum Corp. - Hooker Chem. Corp., subsid. - Hooker Chems. & Plastics Corp., subsid. - Electrochem. Div. & Specialty Chems. Div.<br>PPG Indust., Inc. - Chem. Div. - Indust. Chem. Div.<br>Standard Chlorine Chem. Co., Inc. | Niagara Falls, N. Y.<br>Niagara Falls, N.Y.                     | -<br>-                                       | -<br>-                                                                     |
| Chloro-benzene      | Phenol; chloronitrobenzene; DDT; aniline; solvent carrier for methylene diisocyanate; intermediate & solvent | Syracuse (Solvay), N. Y.<br>Midland, Mich.<br>Sauget, Ill.<br>Henderson, Nev.<br>Niagara Falls, N.Y.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 11.3 (25)<br>136.2 (300)<br>52.2 (115)<br>31.8 (70)<br>6.8 (15) | 183.2 (403.5) -1972                          |                                                                            |
|                     |                                                                                                              | Natrium, W. Va.<br>Delaware City,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 41.3 (91)<br>34 (75)                                            |                                              | Total =<br>313.7 (691)                                                     |

Table A-1. (Continued)

| Chemical               | Usage <sup>1</sup>                                                                                                                                                                                                                                                                 | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                | Location(s) <sup>2,3</sup>                                                                                                                                  | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                    | Total <sup>2,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Chlorobenzene          | Intermediate for the preparation of dyes, fungicides, pharmaceuticals & other organic chemicals                                                                                                                                                                                    | Tenneco Inc. - Tennessee Chems., Inc. - Organics & Polymers Div.                                                                                                                                                              | Fords, N. J.                                                                                                                                                | -                                                                                              | -                                                                           |
| Chlorobenzotrifluoride | Intermediate for pharmaceuticals, dyes & other organic chemicals                                                                                                                                                                                                                   | Tenneco Inc. - Tennessee Chems., Inc. - Organics & Polymers Div.                                                                                                                                                              | Fords, N. J.                                                                                                                                                | -                                                                                              | -                                                                           |
| Chlorodifluoroethane   | Refrigerant; solvent; aerosol propellant; intermediate                                                                                                                                                                                                                             | E. I. du Pont de Nemours & Co., Inc. - Organic Chems. Dept. - Freon® Products Div.<br>Pennwalt Corp. - Chem. Div.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                             | Antioch, Calif.<br>Deerpark, N. J.<br>East Chicago, Ind.<br>Louisville, Ky.<br>McIntire, Mich.<br>Calvert City, Ky.<br>Institute & South Charleston, W. Va. | -<br>-<br>-<br>-<br>-<br>-                                                                     | -<br>-<br>-<br>-                                                            |
| Chloroform             | Fluorocarbon refrigerant & propellants; fluorocarbon plastics; dyes & drugs; general solvent; analytical chemistry; fumigant; insecticides                                                                                                                                         | Allied Chem. Corp. - Specialty Chems. Div.<br>Diamond Shamrock Corp. - Diamond Shamrock Chems. Co. - Electro Chems. Div.<br>Dow Chem. U.S.A.<br>Stauffer Chem. Co. - Indust. Chem. Div.<br>Vulcan Materials Co. - Chems. Div. | Woundsville, W. Va.<br>Belle, W. Va.<br>Freeport, Tex.<br>Louisville, Ky.<br>Geismar, La.<br>Newark, N. J.<br>Mehita, Kans.                                 | 13.6 (30)<br>8.2 (18)<br>45.4 (100)<br>34.1 (75)<br>4.5 (10)<br>13.6 (30)<br>Total = 133 (293) | 106.8 (235.2) - 1972                                                        |
| Chloronaphthalene      | Wax; condenser impregnation; moisture-, flame-, insect-proofing of wood, fabric & other fibrous bodies; molding- & flame-proofing of plastics; solvent (for rubber, cellulose, dyes; mineral & vegetable oils, varnish gums & resins, & other waxes when mixed in the molten state | American Color & Chem. Corp.<br>GAP Corp. - Chem. Div.<br>Koppers Co., Inc. - Organic Materials Div.                                                                                                                          | Lock Haven, Pa.<br>Linden, N. J.<br>Swissville, Pa.                                                                                                         | -<br>-<br>-                                                                                    | -                                                                           |

Table A-1. (Continued)

| Chemical      | Usage                                                                                                                                                                                                                                                                                                                                 | Manufacturer(s)                                                                                                                                                                                                                                                                                      | Location(s)                                                                                                                                                                 | 1975 capacity, MM KZ (MM lb)                                                                                      | Total production MM KZ (MM lb) for year of estimate |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| o-cresol      | See m-cresol                                                                                                                                                                                                                                                                                                                          | Continental Oil Co. - Conaco Chem. - Pitt Conaco Chem.                                                                                                                                                                                                                                               | Newark, N. J.                                                                                                                                                               | -                                                                                                                 | See m-cresol                                        |
|               |                                                                                                                                                                                                                                                                                                                                       | Koppers Co., Inc. - Organic Materials Div. The Merichem Co. Productol Chem. Co.                                                                                                                                                                                                                      | Pollansbee, W. Va.<br>Houston, Tex.<br>Santa Fe Springs, Calif.                                                                                                             | -<br>-<br>-                                                                                                       | -<br>-<br>-                                         |
| p-cresol      | See m-cresol                                                                                                                                                                                                                                                                                                                          | Stinson Lumber Co. - Northwest Petrochem. Corp., div.                                                                                                                                                                                                                                                | Anacortes, Wash.                                                                                                                                                            | -                                                                                                                 | -                                                   |
|               |                                                                                                                                                                                                                                                                                                                                       | American Cyanamid Co. - Organic Chem. Div. The Sherwin-Williams Co. - Sherwin-Williams Chem. Div.                                                                                                                                                                                                    | Bound Brook, N. J.<br>Chicago, Ill.                                                                                                                                         | -<br>-                                                                                                            | See m-cresol                                        |
| Cresylic acid | Phosphate esters; phenolic resins; wire enamel solvent; plasticizers; gasoline additives; laminates coatings for electric motors; disinfectants; metal cleaning compounds; phenolic resins flotation agents; surfactants; chemical intermediates; oil additives; solvent refining or lubricating oils; scouring compounds; pesticides | Continental Oil Co. - Conaco Chem. - Pitt-Conaco Chem. Crowley Tar Products Co., Inc. Koppers Co., Inc. - Organic Materials Div. The Merichem Co. Mobil Oil Corp. - North American Div. Productol Chem. Co. Stinson Lumber Co. - Northwest Petrochem. Corp., div. U.S. Steel Corp. - USS Chem., div. | Newark, N. J.<br>Houston, Tex.<br>Pollansbee, W. Va.<br>Houston, Tex.<br>Benmont, Tex.<br>Pauishore, N. J.<br>Santa Fe Springs, Calif.<br>Anacortes, Wash.<br>Clairton, Pa. | 22.7 (50)<br>-<br>16.0 (35)<br>45.4 (100)<br>1.4 (3)<br>13.5 (30)<br>13.6 (30)<br>0.2 (20)<br>Total = 121.7 (278) | 31.7 (69.9) -1971                                   |

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Table A-1. (Continued)

| Chemical                     | Usage <sup>1</sup>                                                                                                                                                                                                           | Manufacturer(s) <sup>2</sup>                                                                                                                                                                                                                                     | Location(s) <sup>3</sup>                                                                                      | 1975 capacity <sup>2</sup><br>MM kg (MM lb)     | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------------------|
| Chloro-<br>nitro-<br>benzene | Intermediate, especially<br>for dyes; manufacture<br>of p-nitrophenol; from<br>which parathion is made                                                                                                                       | E. I. du Pont de Nemours<br>& Co., Inc. - Organic<br>Chem. Div. - Dyes &<br>Chems. Div.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.                                                                                                                         | Deepwater, N. J.<br>Sauget, Ill.                                                                              | 20.4 (45)<br>43.1 (95)<br>Total =<br>63.5 (140) | -                                                                           |
| Chloro-<br>phenols           | Intermediate in synthesis<br>of dyes & drugs; denatu-<br>rant for alcohol; selec-<br>tive solvent in refining<br>mineral oils                                                                                                | Aldrich Chem. Co., Inc.<br>Dow Chem. U.S.A.<br>Eastman Kodak Co. -<br>Eastman Organic Chems.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.<br>Specialty Organics, Inc.<br>R.S.A. Corp.                                                                        | Milwaukee, Wisc.<br>Midland, Mich.<br>Rochester, N. Y.<br>Sauget, Ill.<br>Twinsdale, Calif.<br>Ardsley, N. Y. | -<br>-<br>-<br>-<br>-<br>-                      | -                                                                           |
| m-chloro-<br>toluene         | Solvent; intermediate                                                                                                                                                                                                        | Occidental Petroleum<br>Corp. - Hooker Chem.<br>Corp., subsid., Hooker<br>Chems. & Plastics Corp.,<br>subsid. - Electrochemi-<br>cal & Specialty Chems.<br>Div.<br>Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>& Polymers Div.<br>(See o-chlorotoluene) | Niagara Falls,<br>Fords, N. J.                                                                                | -<br>-                                          | -                                                                           |
| o-chloro-<br>toluene         | Solvent & intermediate<br>for organic chemicals<br>& dyes                                                                                                                                                                    | Koppers Co., Inc. -<br>Organic Materials Div.                                                                                                                                                                                                                    | Oil City, Pa.                                                                                                 | -                                               | Total m.o.p. cresol<br>= 10.5 (23.1) -1970                                  |
| p-chloro-<br>toluene         | Solvent & intermediates<br>for organic chemicals &<br>dyes                                                                                                                                                                   |                                                                                                                                                                                                                                                                  |                                                                                                               |                                                 |                                                                             |
| m-<br>cresol                 | Disinfectant; phenolic<br>resins; tricresyl phos-<br>phate; ore flotation;<br>textile scouring agent;<br>organic intermediate;<br>mfg. of salicylaldehyde;<br>coumarin, & herbicides;<br>in food antioxidants;<br>surfactant |                                                                                                                                                                                                                                                                  |                                                                                                               |                                                 |                                                                             |

Table A-1. (Continued)

| Chemical            | Use <sup>1</sup>                                                                                                                                                                                                                                                                                            | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                        | Location(s) <sup>2,3</sup>                                                                                                                                                                     | 1974<br>capacity <sup>2</sup><br>MM kg (MM lb)                                                                                        | Totals, s.<br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| Croton-<br>aldehyde | Intermediate for n-<br>butyl alcohol & 2-<br>ethyl-hexyl alcohol;<br>solvent; preparation of<br>rubber accelerators;<br>production of methac-<br>rylate, methacrylates,<br>vinyl acetate, and<br>tear gas; fuel-gas warn-<br>ing agent; organic tan-<br>synthesis; leather tan-<br>ning; alcohol denaturant | Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                                                                                                                                                                                                                                                                                                                                                       | Institute &<br>Charleston, W. Va.                                                                                                                                                              | -                                                                                                                                     | -                                                                 |
| Crotonic<br>acid    | Synthesis of resins,<br>polymers, plasticizers,<br>drugs                                                                                                                                                                                                                                                    | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. - Tenn.<br>Eastman Co., div.                                                                                                                                                                                                                                                                                                                                                                          | Kingsport, Tenn.                                                                                                                                                                               | -                                                                                                                                     | -                                                                 |
| Cumene              | Production of phenol,<br>acetone, & alpha-<br>methylstyrene; solvent                                                                                                                                                                                                                                        | Ashland Oil, Inc. - Ash-<br>land Chem. Co., div. -<br>Petrochems. Div.<br>Clark Oil & Refining<br>Corp. - Clark Chem.<br>Corp., subsid.<br>Coastal States Gas Corp.<br>Coastal States Marketing,<br>Inc., subsid.<br>Dow Chem. U.S.A.<br>Gulf Oil Chems. Co.,<br>div. - Gulf Oil Corp. -<br>Petrochems. Div.<br>Marathon Oil Co.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.<br>Phillips Petroleum Co. -<br>Petrochem & Supply Div.<br>Skelly Oil Co. | Ashland, Ky.<br>Blue Island, Ill.<br>Corpus Christi,<br>Midland, Mich.<br>Philadelphia, Pa.<br>Fort Arthur, Tex.<br>Texas City, Tex.<br>Chocolate Bayou,<br>Phillips, Tex.<br>El Dorado, Kans. | 136.2 (300)<br>50 (110)<br>63.6 (140)<br>4.5 (10)<br>204.3 (450)<br>204.3 (450)<br>95.3 (210)<br>290.6 (640)<br>0.5 (1)<br>63.6 (140) | 135.7 (298) -1974                                                 |

Table A-1. (Continued)

| Chemical      | Use(s)              | Manufacturer(s)                                                                                                                     | Location(s)        | Capacity<br>MW Kg (MW lb) | Total 1955<br>Production<br>MW Kg (MW lb)<br>for year of estimate |
|---------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------|--------------------|---------------------------|-------------------------------------------------------------------|
| Cumene (cont) | (see previous page) | Standard Oil of Calif. -<br>Chevron Chem. Co., sub-<br>sidiary;<br>Ethyl Acetate Additives<br>Indust. Chem. Div. -<br>Indust. Chem. | El Segundo, Calif. | 45.4 (100)                | (see previous page)                                               |
|               |                     | Standard Oil Co. (Ind.)<br>Amoco Chem. Corp.,<br>subsidiary.                                                                        | Texas City, Tex.   | 22.7 (50)                 |                                                                   |
|               |                     | Sun Oil Co. - Sun Oil<br>Co. of Penn., subsidi.<br>Sunlight Refining Co.,<br>subsidiary.                                            | Corpus Christi,    | 113.5 (250)               |                                                                   |
|               |                     | Texaco Inc.                                                                                                                         | Westville, N. J.   | 63.6 (140)                |                                                                   |
|               |                     | Union Carbide Corp. -<br>Union Carbide Caribe,<br>Inc., subsidiary.                                                                 | Fenuelas, P. R.    | 290.6 (640)               |                                                                   |
|               |                     | Union Carbide Corp. -<br>Specialty Chem. Div.                                                                                       | Frankford, Pa.     | 164.8 (362.2)             |                                                                   |
|               |                     | Specialty Chem. Div.                                                                                                                | Gibbstown, N. J.   | -                         |                                                                   |
|               |                     | Rep. - Synthetics Dept.                                                                                                             | Gibbstown, N. J.   | -                         |                                                                   |
|               |                     | Easthold Chem., Inc. -<br>Specialty Chem. Div.                                                                                      | Austin, Tex.       | -                         |                                                                   |
|               |                     | Kay-Fries Chem., Inc.                                                                                                               | Stony Point, N. Y. | -                         |                                                                   |
|               |                     | Wack Chem., Inc.                                                                                                                    | Memphis, Tenn.     | -                         |                                                                   |
|               |                     | PMC Corp. - Chem. Group -<br>Indust. Chem. Div.                                                                                     | South Charleston,  | -                         |                                                                   |
|               |                     | Monsanto Co. - Monsanto<br>Indust. Chem. Co.                                                                                        | Everett, Mass.     | -                         |                                                                   |
|               |                     | Ciba-Geigy Corp. -<br>Agricultural Div.                                                                                             | McIntosh, Ala.     | -                         |                                                                   |
|               |                     | Wack Chem., Inc.                                                                                                                    | St. Gabriel, La.   | -                         |                                                                   |
|               |                     | Wack Chem., Inc.                                                                                                                    | Memphis, Tenn.     | -                         |                                                                   |



Table A-1. (Continued)

| Chemical     | Use(s)                                                                                                                                                                                                                                                                                         | Manufacturer(s)                                                    | Location(s)          | 1975 capacity, MM kg (MM lb.) | Total's production, MM kg (MM lb.) for year of estimate |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|----------------------|-------------------------------|---------------------------------------------------------|
| Cyclohexane  | Manufacture of nylon; solvent for cellulose ethers, fats, oils, waxes, bitumens, resins, crude rubber; extracting essential oils; chemical (organic synthesis, re-crystallizing medium); paint & varnish remover; glass substitutes; vapor has been used as lubricant for steel (experimental) | American Petrofina, Inc.                                           | Big Spring, Tex.     | 45.3 (99.8)                   | 1062.4 (2340)                                           |
|              |                                                                                                                                                                                                                                                                                                | Cosden Oil & Chem. Co., subsid.                                    |                      |                               | -1974                                                   |
|              |                                                                                                                                                                                                                                                                                                | Commonwealth Oil Refining Co., Inc. - Coreco                       | Pensacola, F. R.     | 117.7 (259.2)                 |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Cyclohexane, Inc. - subsid.                                        |                      |                               |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Exxon Corp. - Exxon Chem. Co., div. - Exxon Chem. Co. U.S.A.       | Baytown, Tex.        | 117.7 (259.2)                 |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Gulf Oil Corp. - Gulf Oil Chem. Co., div. - Petrochems. Div.       | Port Arthur, Tex.    | 97.1 (213.8)                  |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Phillips Petroleum Co. -                                           |                      |                               |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Phillips Puerto Rico Core Inc., subsid.                            | Borger, Tex.         | 117.7 (259.2)                 |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Phillips                                                           | Sweeny, Tex.         | 252.8 (556.8)                 |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Texaco Inc.                                                        | Guayama, F. R.       | 214.7 (473)                   |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Union Oil Co. of Calif.                                            | Port Arthur, Tex.    | 117.7 (259.2)                 |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Union Pacific Corp. -                                              | Beaumont, Tex.       | 100 (220.3)                   |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Champion Petroleum Co., subsid.                                    | Corpus Christi, Tex. | 67 (147.6)                    |                                                         |
| Total =      |                                                                                                                                                                                                                                                                                                |                                                                    |                      | 1323.4 (2915.1)               |                                                         |
| Cyclohexanol | Soap making; to incorporate in cosmetics & pharmaceuticals; source of adipic acid for nylon; textile finishing solvent; blending agent; lacquers; paints & varnishes; finish removers; dry cleaning; emulsified products; leather degreasing; polishes; plasticizers; pesticides; germicides   | Allied Chem. Corp. - Fibers Div.                                   | Hopewell, Va.        | -                             | 325.5 (716.3)                                           |
|              |                                                                                                                                                                                                                                                                                                | Celanese Corp. - Celanese Chem. Co., div.                          | Bay City, Tex.       | -                             | -1968                                                   |
|              |                                                                                                                                                                                                                                                                                                | Dow Badische Co.                                                   | Freeport, Tex.       | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                | El Paso Products Co., subsid. - El Paso Natural Gas Co.            | Odessa, Tex.         | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Monsanto Co. - Monsanto Indust. Chems. Co. - Monsanto Textiles Co. | Luling, La.          | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Nippro, Inc.                                                       | Pensacola, Fla.      | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                | Rohm & Haas Co. - Rohm & Haas Ky. Inc., subsid.                    | Augusta, Ga.         | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                |                                                                    | Louisville, Ky.      | -                             |                                                         |
|              |                                                                                                                                                                                                                                                                                                |                                                                    |                      |                               |                                                         |
|              |                                                                                                                                                                                                                                                                                                |                                                                    |                      |                               |                                                         |
|              |                                                                                                                                                                                                                                                                                                |                                                                    |                      |                               |                                                         |
|              |                                                                                                                                                                                                                                                                                                |                                                                    |                      |                               |                                                         |

Table A-1. (Continued)

| Chemical        | Use <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                           | Location(s) <sup>3</sup>                                                                                                             | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                              | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Cyclohexane     | Organic synthesis; particularly of adipic acid & caprolactam (about 95%); polyvinyl chloride & its copolymers, & methacrylate ester polymers; solvent for DDT in aerosol bombs; general wood stains; paint & varnish removers; spot & stain removers; degreasing of metals; in polishes; leveling agent in dyeing & de- staining silk; lubricant additive; general solvent | Allied Chem. Corp. - Fibers Div.<br>Celanese Corp. - Celanese Chem. Co., div.<br>Dow Badische Co.<br>El Paso Natural Gas Co. - El Paso Products Co., subsid.<br>Monsanto Co. - Monsanto Textiles Co.<br>Nippro, Inc.<br>Rohm & Haas Co. - Rohm & Haas Ky. Inc. - subsid.<br>Union Carbide Corp. - Chems. & Plastics Div. | Hartwell, Va.<br>Bay City, Tex.<br>Freeport, Tex.<br>Odessa, Tex.<br>Pensacola, Fla.<br>Augusta, Ga.<br>Louisville, Ky.<br>Taft, La. | 157.1 (346)<br>45.4 (100)<br>113.5 (250)<br>29 (64)<br>227 (500)<br>68.1 (150)<br>18.2 (40)<br>31.8 (70) | 343.5 (756.5) -1971                                                         |
| Cyclohexene     | Organic synthesis; catalyst solvent; oil extraction                                                                                                                                                                                                                                                                                                                        | Phillips Petroleum Co. - Petrochem. & Supply Div.<br>Uniroyal, Inc. - Uniroyal Chem., div.                                                                                                                                                                                                                               | Phillips, Tex.<br>Nagaruck, Conn.                                                                                                    | -<br>-                                                                                                   | -                                                                           |
| Cyclohexylamine | Boiler-water treatment; corrosion inhibitor in boilers; rubber accelerator; intermediate                                                                                                                                                                                                                                                                                   | Abbott Labs. - Chem. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.<br>Virginia Chems., Inc. - Indust. Chems. Dept.                                                                                                                                                                                                  | Wichita, Kans.<br>Sauget, Ill.<br>Portsmouth, Va.                                                                                    | 4.5 (10)<br>1 (2)<br>3.6 (8)                                                                             | -<br>Total =<br>9.1 (20)                                                    |
|                 |                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                          |                                                                                                                                      | Total =<br>701.4 (1545)                                                                                  |                                                                             |

Table A-1. (Continued)

| Chemical                      | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                           | Location(s) <sup>2,3</sup>                                                                     | 1975<br>capacity <sup>2</sup><br>MM KG (MM lb.) | Total <sup>4,5</sup><br>production<br>MM KG (MM lb.)<br>for year of estimate |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------------------------------|
| Decehydr-<br>naphtha-<br>lene | Solvent for oils, fats,<br>waxes, resins, rubber,<br>etc.; substitute for<br>turpentine; staining<br>machinery; steam-<br>mover; shoe creams;<br>floor waxes, etc.;<br>cleaning fluids;<br>lubricants                                                                                                                                                                                                                                                                                                                                                                | E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Organic Chems. Dept. -<br>Dyes & Chems. Div.<br>Lonza Inc.                                | Deepwater, N. J.<br><br>Mapleton, Ill.                                                         | -<br>-                                          | -<br>-                                                                       |
| Decanol                       | Plasticizers; deter-<br>gents; synthetic lubri-<br>cants; solvents; per-<br>fumes; flavorings                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Continental Oil Co. -<br>Conoco Chems.<br>The Proctor & Gamble<br>Co.                                                                    | Westlake, La.<br>Ivorydale, Ohio                                                               | -<br>-                                          | -<br>-                                                                       |
| Diacetone<br>alcohol          | Solvent for nitro-<br>cellulose, cellulose<br>acetate, various oils,<br>resins, waxes, fats,<br>dyes, tars; lacquers;<br>dopes, coating composi-<br>tion; wood preservative;<br>stains; rayon & artificial<br>leather; imitation gold<br>leaf; dyeing mixtures;<br>textile finishes;<br>extraction of resins &<br>waxes; preservative for<br>animal tissues; metal-<br>cleaning compounds;<br>hydraulic compression<br>fluids; stripping<br>agent (textiles); labora-<br>tory reagent; the techni-<br>cal grade, containing<br>acetone, has greater<br>solvent power | Celanese Corp. - Ceta-<br>nese Chem. Co., div.<br>Shell Chem. Co. -<br>Base Chems.<br>Union Carbide Corp. -<br>Chems. & Plastics<br>Div. | Fishof, Tex.<br>Deer Park, Tex.<br>Domingue, Calif.<br>Institute & South<br>Charleston, W. Va. | -<br>-<br>-<br>-                                | -<br>-<br>-<br>-                                                             |
| Diamino-<br>benzoic<br>acid   | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Rofors Indust., Inc.<br>Salisbury Labs.                                                                                                  | Linden, N. J.<br>Wilmington, N. C.                                                             | -<br>-                                          | -<br>-                                                                       |

Table A-1. (Continued)

| Chemical                        | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                               | Location(s) <sup>2,3</sup>                                                                                                                                                                                                       | 1975 capacity <sup>2</sup><br>MM lb (MM lb)                                                                                                        | Total <sup>4,5</sup><br>Production<br>MM lb (MM lb)<br>for year of estimate |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Dichloro-<br>benzene<br>(m,o,p) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                  |                                                                                                                                                    |                                                                             |
|                                 | Mfg. of 3,4-dichloro-<br>aniline; solvent for a<br>wide range of organic<br>materials & for oxides<br>of cerium, cerium, iron,<br>cobalt, chromium, nickel;<br>production of toluene<br>diisocyanate; dye manu-<br>facturing; fumigant &<br>insecticide; degreasing<br>hides & wool; metal<br>polishes, industrial<br>odor control; moth<br>repellent; germicide<br>space odorant; manu-<br>facture of 2,5-dichloro-<br>aniline; dyes;<br>intermediates; pharmacy;<br>agriculture (fumigat-<br>ing soil) | Blue Spruce Co.<br>Eastman Kodak Co. -<br>Eastman Organic Chem.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Organic Chems. Dept. -<br>Dyes & Chems. Div.<br>Monsanto Co. -<br>Monsanto Indust. Chems.<br>Co.                                                                                                                                                                           | Edison, N. J.<br>Rochester, N. Y.<br>Deepwater, N. Y.<br>Luling, La.                                                                                                                                                             | -<br>-<br>-<br>-                                                                                                                                   | -                                                                           |
|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Allied Chem. Corp. - Chem.<br>Indust. Chem. Div. - Chem.<br>Products Corp.<br>Dow Chem. U.S.A.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.<br>Occidental Petroleum<br>Corp. - Hooker Chem.<br>Corp., & Hooker<br>Chem. & Plastics Corp. -<br>subsid. - Electrochemical<br>& Specialty Chems. Div.<br>PPG Indust., Inc. - Chem.<br>Div. - Indust. Chems. Div.<br>Solvent Chem. Co., Inc. | Syracuse (Solway),<br>Carterville, Ill.<br>Midland, Mich.<br>Sauget, Ill.<br>Niagara Falls,<br>N. Y.<br>Natrium, N. Va.<br>Malden, Mass.<br>Niagara Falls,<br>N. Y.<br>Irwindale, Calif.<br>Delaware City, Del.<br>Nearby, N. J. | 9 (20)<br>2.3 (5)<br>14.1 (31)<br>12.7 (28)<br>-<br>21.3 (47)<br>1.8 (3)<br>9.1 (20)<br>1.8 (3)<br>27.2 (60)<br>7.3 (16)<br>Total =<br>105.8 (233) | 53.4 (139.7) -1972                                                          |

Table A-1. (Continued)

| Chemical                                               | Use <sup>1</sup>                                                                                                                                                                                                                                                                                                         | Manufacturer(s) <sup>2,3</sup>                                                            | Location(s) <sup>2,3</sup>                                                                | 1975 capacity, <sup>2</sup><br>MM kg (MM lb) | Total <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------|
| Dichloro-<br>ethylene<br>(vinyl-<br>idene<br>chloride) | General solvent for<br>organic materials; dye<br>extraction; perfumes;<br>lacquers; thermoplastics;<br>organic synthesis;<br>medicine; copolymerized<br>with vinyl chloride or<br>acrylonitrile to form<br>various kinds of<br>saran; other copolymers<br>are also made; adhesives;<br>component of synthetic<br>fibers  | Low Chem. U.S.A.<br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div.             | Freeport, Tex.<br>Flaguana, La.<br>Lake Charles, La.                                      | -<br>-<br>-                                  | -                                                                           |
| Dichloro-<br>ethyl<br>ether                            | General solvent; selec-<br>tive solvent for produc-<br>tion of high-grade lubri-<br>cating oils; textile<br>scouring & cleansing;<br>fulling compounds; wet-<br>ting & penetrating com-<br>pounds; organic synthe-<br>sis; paints, varnishes,<br>lacquers; finish removers;<br>spotting & dry cleaning;<br>soil fumigant | Buckman Labs., Inc.<br>Dow Chem. U.S.A.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. | Cadet, Mo.<br>Memphis, Tenn.<br>Freeport, Tex.<br>Institute & South<br>Charleston, W. Va. | -<br>-<br>-                                  | -                                                                           |
| Dichloro-<br>hydrin                                    | General solvent; inter-<br>mediate in organic syn-<br>thesis; paints, varnishes,<br>lacquers, celluloid<br>cements; water colors;<br>binder; photographic<br>lacquers                                                                                                                                                    | Eastman Kodak Co. -<br>Eastman Organic Chems.                                             | Rochester, N. Y.                                                                          | -                                            | -                                                                           |
| Dichloro-<br>pentane                                   | Solvent for oils, greases,<br>rubber, resins & bi-<br>tuminous materials; removal<br>of tar; reclaiming rubber;<br>paint & varnish removers;<br>degreasing of metals;<br>insecticide, soil fumi-<br>gant; removal of wax<br>deposits on oil-well<br>equipment                                                            | -                                                                                         | -                                                                                         | -                                            | -                                                                           |

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Table A-1. (Continued)

| Chemical                    | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                       | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                               | Location(s) <sup>2,3</sup>                                                                                                           | 1975 capacity, <sup>2</sup><br>MM kg (MM lb)                                   | Total <sup>4</sup> production<br>MM kg (MM lb)<br>for year of estimate |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Dichloro-<br>propene        | Organic synthesis;<br>soil fumigants                                                                                                                                                                                                                                                                                                                                                                     | Tow Chemical U.S.A.                                                                                                                                                                                                                                                                          | Freeport, Tex.                                                                                                                       | -                                                                              | -                                                                      |
| Dicyclo-<br>hexyl-<br>amine | Intermediate; insecti-<br>cides; plasticizer;<br>corrosion inhibitors;<br>antioxidants in rubber;<br>lubricating oils, fuels;<br>catalysts for paint,<br>varnishes & inks;<br>detergents; extractant                                                                                                                                                                                                     | Abbott Labs. - Chem.<br>Div.<br>Va. Chems. Inc. -<br>Indust. Chems. Dept.                                                                                                                                                                                                                    | Wichita, Kans.<br><br>Portsmouth, Va.                                                                                                | -<br>-                                                                         | -<br>-                                                                 |
| Diethanol-<br>amine         | Liquid detergents for<br>emulsion paints, cutting<br>oils, shampoos, cleaners,<br>& polishes; textile<br>specialties; absorbent<br>for acid gases; chemical<br>intermediate for resins &<br>plasticizers, etc.;<br>solubilizing 2,4-D                                                                                                                                                                    | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>Tow Chem. U.S.A.<br><br>Olin Corp. - Designed<br>Products Div.<br>Texaco Inc. - Jefferson<br>Chem. Co., Inc., subd.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                      | Orange, Tex.<br><br>Freeport, Tex.<br>Midland, Mich.<br>Brandenburg, Ky.<br><br>Port Neches, Tex.<br><br>Seardrift, Tex.             | 9.1 (20)<br>13.6 (30)<br>15.9 (35)<br>11.3 (25)<br><br>34 (75)<br>113.5 (250)  | 50.4 (111)<br>-1974                                                    |
| Diethylene<br>glycol        | Polyurethane & unsatu-<br>rated polyester resins;<br>triethylene glycol; tex-<br>tile softener; petroleum<br>solvent extraction; de-<br>hydration of natural gas;<br>plasticizers & surfac-<br>tants; cellulose & many<br>other polymers; humectant<br>for tobacco, casing,<br>synthetic sponges, paper<br>products; cork composi-<br>tions; book-binding<br>adhesives; dyeing as-<br>sistant; cosmetics | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>BASF Wyandotte Corp. -<br>Indust. Chems. Group<br>Celanese Corp. -<br>Celanese Chem. Co., div.<br>Dixie Chem. Co.<br>Dow Chem. U.S.A.<br><br>Eastman Kodak Co. - East-<br>man Chem. Products, Inc.,<br>subd. - Texas East-<br>man Co., div. | Orange, Tex.<br><br>Geismar, La.<br><br>Clear Lake, Tex.<br><br>Bayport, Tex.<br>Freeport, Tex.<br>Plaquemine, La.<br>Longview, Tex. | 4.5 (10)<br>9.5 (21)<br><br>10.9 (24)<br><br>10.9 (24)<br>21.3 (47)<br>3.6 (8) | 122 (268.7)<br>-1973                                                   |

<sup>1</sup> Includes mono- and tri-ethanol amines

Table A-1. (Continued)

| Chemical                                   | Usage <sup>1</sup><br>(see previous page)                                                                            | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                           | Location(s) <sup>2,3</sup>                                                                                                                                                                  | 1975<br>capacity <sup>2</sup><br>MM kg (NM lb)                                       | Totals <sup>2,3</sup><br>Production<br>MM kg (NM lb)<br>for year of production<br>(see previous page) |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Diethylene glycol (Con't)                  |                                                                                                                      | Northern Natural Gas Co., Northern Petro-chem. Co. subsid. - Polymers Div.<br>Olin Corp. - Designed Products Div.<br>PPG Indust., Inc. - Chem. Div. - Houston Chem. Co., div. - PPG Indust. (Caribe)<br>Shell Chem. Co. - Base Chem.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Union Carbide Caribe, Inc., subsid.                                          | Morris, Ill.<br>Brandenburg, Ky.<br>Beaumont, Tex.<br>Guaynilla, P. R.<br>Geismar, La.<br>Port Neches, Tex.<br>Sadrift, Tex.<br>Tart, La.<br>Penuelas, P. R.                                | 13.6 (30)<br>2.3 (5)<br>4.5 (10)<br>18.2 (40)<br>4.5 (10)<br>16.3 (36)<br>97.6 (215) |                                                                                                       |
|                                            |                                                                                                                      | Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>Shell Chem. Co. - Base Chem.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tex. Eastman Co., div.<br>Union Carbide Corp. - Chems. & Plastics Div. | Midland, Mich.<br>Longview, Tex.<br>Brandenburg, Ky.<br>Geismar, La.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va.<br>Longview, Tex.<br>Institute & South Charleston, W. Va. | -<br>-<br>-<br>-<br>-<br>-<br>-                                                      | 6.8 (15)<br>-1972                                                                                     |
| Diethylene glycol mono-butyl ether         | Solvent for nitro-cellulose, oils, dyes, gums, soaps, polymers; plasticizer intermediate                             |                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                             | Total =<br>218 (480)                                                                 |                                                                                                       |
| Diethylene glycol mono-butyl ether acetate | Solvent for oils, resins, gums, also for cellulose nitrate & polymeric coatings; plasticizers in lacquers & coatings |                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                             |                                                                                      |                                                                                                       |

Table A-1. (Continued)

| Chemical                             | Useage                                                                                                                                                                                                                                                                                          | Manufacturer(s)                                                                                                                                                                                                                                                                                                                               | Location(s)                                                                                                                                         | 1975 capacity<br>MW kg (MM lb) | 1972<br>MW kg (MM lb) | Total U.S.<br>production<br>MW kg (MM lb)<br>for year of estimate |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-----------------------|-------------------------------------------------------------------|
| Diethylene glycol ether              | Solvent for dyes, nitro-cellulose, & resins. emul-sional solvent for mineral oil-soap & mineral oil-sulfonated oil mixtures; nonaqueous stains for wood; for setting the twist & conditioning yarns & cloth; textile printing; textile soaps; lacquers; organic syn-thesis; brake fluid diluent | Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>Shell Chem. Co. - Base Chem.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chem. & Plastics Div.                                                             | Midland, Mich.<br>Longview, Tex.<br>Brandenburg, Ky.<br>Geismar, La.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va.                   | -<br>-<br>-<br>-<br>-<br>-     | 20.4 (45)             | -1972                                                             |
| Diethylene glycol mono-ether acetate | Solvent for cellulose esters, gums, resins, coatings & lacquers; printing inks                                                                                                                                                                                                                  | -                                                                                                                                                                                                                                                                                                                                             | -                                                                                                                                                   | -                              | -                     | -                                                                 |
| Diethylene glycol mono-ether acetate | -                                                                                                                                                                                                                                                                                               | -                                                                                                                                                                                                                                                                                                                                             | -                                                                                                                                                   | -                              | -                     | -                                                                 |
| Diethylene glycol mono-ether         | Solvent; brake fluid component; intermediate                                                                                                                                                                                                                                                    | Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>PPG Indust., Inc. - Chem. Div. - Houston Chem. Co., div.<br>Shell Chem. Co. - Base Chem.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chem. & Plastics Div. | Midland, Mich.<br>Longview, Tex.<br>Brandenburg, Ky.<br>Beaumont, Tex.<br>Geismar, La.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va. | -<br>-<br>-<br>-<br>-<br>-     | 6.8 (15)              | -1972                                                             |



Table A-1. (Continued)

| Chemical                                    | Use <sup>1</sup>                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                                       | Location(s) <sup>2,3</sup>                                          | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Diethylene glycol mono-methyl ether acetate | Solvent                                                                                                                                                                                            | -                                                                                                                                                    | -                                                                   | -                                           | -                                                                           |
| Diethylene glycol dibutyl ether             | High-boiling, inert solvent with application in extraction processes & in coatings & adhesives; solvent for vinyl chloride dispersions; extractant for uranium ores                                | Union Carbide Corp. - Chems. & Plastics Div.                                                                                                         | Institute & South Charleston, W. Va.                                | -                                           | -                                                                           |
| Diethylene glycol diethyl ether             | Solvent for nitrocellulose; resins, lacquers; high-boiling medium & solvent for organic synthesis                                                                                                  | Union Carbide Corp. - Chems. & Plastics Div.                                                                                                         | Institute & South Charleston, W. Va.                                | -                                           | -                                                                           |
| Diethylene glycol dimethyl ether            | Solvent; anhydrous reaction media for organometallic syntheses                                                                                                                                     | The Ansul Co. - Chem. Div.<br>Olin Corp. - Designed Products Div.                                                                                    | Marquette, Wisc.<br>Rochester, N. Y.                                | -                                           | -                                                                           |
| Diethylamine                                | Rubber chemicals; textile specialties; selective solvent; dyes; flotation agents; resins; pesticides; polymerization inhibitors; pharmaceuticals; pesticides; electroplating; corrosion inhibitors | Air Products & Chems., Inc.<br>Pennwalt Corp. - Chem. Div.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Va. Chems. Inc. - Indust. Chems. Dept. | Pensacola, Fla.<br>Wyandotte, Mich.<br>Taft, La.<br>Portsmouth, Va. | -                                           | 5 (11.1) -1972                                                              |
| Diethyl sulfate                             | Ethylating agent in organic synthesis                                                                                                                                                              | Union Carbide Corp. - Chems. & Plastics Div.                                                                                                         | Institute & South Charleston, W. Va.                                | -                                           | -                                                                           |

Table A-1. (Continued)

| Chemical            | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                      | Location(s) <sup>2,3</sup>                                                     | 1975<br>capacity <sup>2</sup><br>MM lb (MM lb) | Total <sup>2,3</sup><br>production<br>MM lb (MM lb)<br>for year of estimate |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Trifluoroethane     | Refrigerant; aerosol propellant; intermediate                                                                                                                                                                                                                                                        | Allied Chem. Corp. - Specialty Chem. Div.<br>E. I. du Pont de Nemours & Co., Inc. - Organic Chem. Dept. - Freon products div.                                                                       | Saton Rouge, La.<br>Louisville, Ky.                                            | -                                              | -                                                                           |
| Diisobutylene       | Alkylation; intermediates; antioxidants; surfactants; lube additives; plasticizers; rubber chemicals                                                                                                                                                                                                 | The R. F. Goodrich Co. - B. F. Goodrich Chem. Co., div.<br>Petro-Tex Chem. Corp. - Petro-Tex Chem. Co., subsid.<br>Texaco Inc.                                                                      | Port Neches, Tex.<br>Houston, Tex.<br>Port Arthur, Tex.                        | -                                              | -                                                                           |
| Diketene            | Production of acetone-arylamides; pigments; solvents; plasticizers; food preservatives; pharmaceutical intermediates                                                                                                                                                                                 | Eastman Kodak Co. - Eastman Chem. Products, Inc. subsid. - Tenn. Eastman Co., div.<br>PMC Corp. - Chem. Group - Indust. Chem. Div.                                                                  | Kingsport, Tenn.<br>Meadville, Pa.                                             | -                                              | -                                                                           |
| Dimethylamine       | Acid gas absorbent; solvent; anti-oxidant; methylamine; formaldehyde; dimethylacetamide; dyes; flotation agent; gasoline stabilizers; pharmaceuticals; textile chemicals; rubber accelerators; electroplating; dehairing agent; missile fuels; pesticide propellant; rocket propellants; surfactants | Air Products & Chemicals, Inc.<br>Commercial Solvents Corp.<br>E. I. du Pont de Nemours & Co., Inc. - Biochem. Dept.<br>GAP Corp. - Chem. Div.                                                      | Pennacola, Fla.<br>Terre Haute, Ind.<br>Belle, W. Va.<br>Calvert City, Ky.     | -                                              | 55.2 (121.5) -1973                                                          |
| N,N-dimethylaniline | Dyes; intermediates; solvent; manufacture of anilino; stabilizer (acid acceptor)                                                                                                                                                                                                                     | Allied Chem. Corp. - Specialty Chem. Div.<br>American Cyanamid Co. - Organic Chem. Div.<br>E. I. du Pont de Nemours & Co., Inc. - Organic Chem. Dept. - Dyes & Chem. Dept.<br>Dye Specialties, Inc. | Buffalo, N. Y.<br>Round Brook, N. J.<br>Deepwater, N. J.<br>Jersey City, N. J. | -                                              | -                                                                           |

Table A-1. (Continued)

| Chemical             | Usage                                                                                                                                                                                                                                                                                                                                            | Manufacturer(s) <sup>2,3</sup>                                                                                                        | Location(s) <sup>2,3</sup>                                | 1975 capacity <sup>1</sup><br>MM kg (MM lb) | Total <sup>1,2,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------------------------|
| Dimethyl ether       | Refrigerant; solvent; extraction agent; propellant for sprays; chemical (reaction medium); catalyst & stabilizer in polymerization                                                                                                                                                                                                               | E. I. du Pont de Nemours & Co., Inc. -<br>Petrochem. Dept.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                          | Belle, W. Va.<br>Institute & South<br>Charleston, W. Va.  | -                                           | -                                                                             |
| N,N-diethylformamide | Solvent for vinyl resins & acrylene, butadiene, acid esters; catalyst in carboxylation reactions; organic synthesis                                                                                                                                                                                                                              | Air Products & Chem., Inc.<br>E. I. du Pont de Nemours & Co., Inc. -<br>Petrochem. Dept.<br>Lachar Chem. Inc.                         | Pensacola, Fla.<br>Belle, W. Va.<br>Chicago Heights, Ill. | -                                           | -                                                                             |
| Dimethyl sulfate     | Methylating agent for amines & phenols                                                                                                                                                                                                                                                                                                           | E. I. du Pont de Nemours & Co., Inc. -<br>Petrochem. Dept.<br>Indust. Chem. Dept.                                                     | Belle, W. Va.<br>Linden, N. J.                            | -                                           | -                                                                             |
| Dimethyl sulfide     | Gas odorant; solvent for many inorganic substances; catalyst impregnator                                                                                                                                                                                                                                                                         | Crown Cellulose Corp. -<br>Chem. Products Div.<br>Fennwalt Corp. - Chem. Div.<br>Phillips Petroleum Co. -<br>Petrochem. & Supply Div. | Bogalusa, La.<br>Beaumont, Tex.<br>Phillips, Tex.         | -                                           | -                                                                             |
| Dimethyl sulfoxide   | Solvent for polymerization & cyanide reactions; analytical reagent; spinning polyacrylonitrile & other synthetic fibers; industrial cleaners pesticides, paint stripping, hydraulic fluids, preservation of cells at low temperatures; diffusion of drugs, etc.; into blood stream by topical application; medicine; plant pathology & nutrition | Crown Cellulose Corp. -<br>Chem. Products Div.                                                                                        | Bogalusa, La.<br>Canas, Wash.                             | -                                           | -                                                                             |

Table A-1. (Continued)

| Chemical                    | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                    | Manufacturer(s) <sup>2,3</sup>                                                                                                                  | Location(s) <sup>2,3</sup>                                                    | 1976<br>capacity <sup>2</sup><br>MM KG (MM lb.) | Total <sup>2,3</sup><br>production<br>MM KG (MM lb.)<br>for year of estimate |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------------------------------|
| Dinitro-<br>benzene         | Organic synthesis;<br>dyes; camphor substitute<br>in celluloid production                                                                                                                                                                                                                                                                                                                                                                             | -                                                                                                                                               | -                                                                             | -                                               | -                                                                            |
| Dinitro-<br>benzoic<br>acid | -                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Ashland Oil, Inc. - div. -<br>Ashland Chem. Co., div. -<br>Chem. Products Div.<br>Rohm & Haas Co., Inc.<br>Salsbury Labs.                       | Great Meadows,<br>Linden, N. J.<br>Charles City,<br>Iowa                      | -                                               | -                                                                            |
| Dinitro-<br>toluene         | Organic synthesis;<br>toluidines; dyes;<br>explosives                                                                                                                                                                                                                                                                                                                                                                                                 | Air Products & Chems.,<br>Inc.<br>E. I. du Pont de Nemours & Co., Inc. -<br>Organic Chems. Dept. -<br>Dyes & Chems. Div.<br>Ruticon Chems. Inc. | Pensacola, Fla.<br>Deerwater, N. J.<br>Geismar, La.                           | -                                               | -                                                                            |
| Dioxane                     | Solvent for celluloses<br>& wide range of organic<br>products; lacquers;<br>paints; varnishes;<br>paint; varnishes;<br>solvent; wetting & dis-<br>persing agent in tex-<br>tile processing; dye<br>baths; stain and print-<br>ing compositions;<br>cleaning & detergent<br>preparations; cements;<br>cosmetics; deodorants;<br>fumigants; emulsions;<br>polishing compositions;<br>stabilizer for chlori-<br>nated solvents; paint;<br>lotion counter | Dow Chem. U.S.A.<br>Ferro Corp. - Grant<br>Chem. Div.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                        | Fresport, Tex.<br>Baton Rouge, La.<br>Institute & South<br>Charleston, W. Va. | -                                               | -                                                                            |
| Dioxo-<br>lane              | Leaching solvent &<br>extraction for oils,<br>fats, waxes, dyes, &<br>cellulose derivatives                                                                                                                                                                                                                                                                                                                                                           | Ferro Corp. - Grant<br>Chem. Div.                                                                                                               | Baton Rouge, La.                                                              | -                                               | -                                                                            |

Table A-1. (Continued)

| Chemical           | Usage                                                                                                                                                   | Manufacturer(s)                                                                                                                                                                    | Location(s)                                                                                                    | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                         | Total <sup>1,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Diphenyl-amine     | Rubber antioxidants & accelerators; stabilizers for plastics; solid rocket propellants; pesticides; explosives; dyes; pharmaceuticals                   | American Cyanamid Co. - Organic Chems. Div.<br>E. I. du Pont de Nemours & Co., Indust. Chems. Dept.<br>First Mississippi Corp. - First Chem. Corp., SUBSIS.<br>Rubicon Chems. Inc. | Bound Brook, N. J.<br>Gibbstown, N. J.<br>Pasadena, Miss.<br>Gelsmar, La.<br>Midland, Mich.                    | -<br>-<br>-<br>-<br>-                                               | -                                                                           |
| Diphenyl-oxide     | Organic synthesis; perfumery, particularly soaps; heat-transfer medium; resins for laminated electrical insulation                                      | Dow Chem. U.S.A.                                                                                                                                                                   |                                                                                                                | -                                                                   | -                                                                           |
| Diphenyl-thiourea  | Intermediates; dyes (sulfur colors, indigo); methyl indigo; oxidation accelerators; synthesis of dyes; pharmaceuticals; flotation agent; acid inhibitor | American Cyanamid Co. - Organic Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.                                                                                          | Bound Brook, N. J.<br>Mitre, W. Va.                                                                            | -<br>-                                                              | -                                                                           |
| Dipropylene glycol | Solvent for nitrocellulose; shellac; partial solvent for cellulose acetate; solvent mixtures; lacquers; coatings; printing inks                         | Dow Chem. U.S.A.<br>Olin Corp. - Designed Products Div.<br>Oxirane Chem. Co., Texaco Inc., Jefferson Chem. Co., Inc., Subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.      | Freeport, Tex.<br>Flaquemine, La.<br>Frankfort, Ky.<br>Bayport, Tex.<br>Port Neches, Tex.<br>Institute & South | 15.9 (35)<br>5.4 (12)<br>2.3 (5)<br>5.9 (13)<br>3.2 (7)<br>5.4 (12) | 24.2 (53.3) -1973                                                           |
|                    |                                                                                                                                                         |                                                                                                                                                                                    |                                                                                                                | Total =<br>38.1 (84)                                                |                                                                             |

Table A-1. (Continued)

| <u>Chemical</u> | <u>Usage<sup>1</sup></u>                                                                                                                                                                     | <u>Manufacturer(s)<sup>2,3</sup></u>                                                                                                                                                                                                                                                                                             | <u>Location(s)<sup>2,3</sup></u>                                                                                                                                                                             | <u>capacity<sup>2</sup><br/>MM kg (MM lb)</u> | <u>Total<sup>2,5</sup><br/>production<br/>MM kg (MM lb)<br/>for year of estimate</u> |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------|
| Dodecene        | Flavors; perfumes;<br>medicine; oils; dyes;<br>resins                                                                                                                                        | Atlantic Richfield Co. -<br>ARCO Chem. Co., div.<br>Continental Oil Co. -<br>Conoco Chems.<br>Exxon Corp. - Exxon<br>Chem. Co.; div. -<br>Exxon Chem. Co. U.S.A.<br>Gulf Oil Corp. - Gulf<br>Oil Chems. Co., div.<br>Petrochens. Div.<br>The Humphrey Chem. Co.<br>Sun oil Co. - Sun Oil<br>Co. of Penn., subsid.<br>Texaco Inc. | - Wilmington, Calif.<br>- Westlake, La.<br>- Baton Rouge, La.<br><br>Cedar Bayou, Tex.<br><br>North Haven, Conn.<br>Duncan, Okla.<br>Marcus Hook, Pa.<br>Toledo, Ohio<br>Port Arthur, Tex.<br>Beaumont, Tex. | -<br>-<br>-<br>-<br>-<br>-<br>-               | -                                                                                    |
| Dodecyl-aniline | Intermediate                                                                                                                                                                                 | Monsanto Co. of Calif.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.                                                                                                                                                                                                                                                          | Sauget, Ill.                                                                                                                                                                                                 | -                                             | -                                                                                    |
| Dodecyl-phenol  | Solvent; intermediate<br>for surface-active<br>agents; oil additives;<br>resins; fungicides;<br>bactericides; dyes;<br>pharmaceuticals; ad-<br>hesives; rubber<br>chemicals                  | GAF Corp. - Chem. Div.<br>Monsanto Co. - Monsanto<br>Indust. Chems. Co.<br>Productrol Chem. Co.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                                                                                                               | Calvert City, Ky.<br>Kearny, N. J.<br><br>Santa Fe Springs,<br>Calif.<br>Marietta, Ohio                                                                                                                      | -<br>-<br>-<br>-                              | -                                                                                    |
| Epichlorohydrin | Major raw material for<br>epoxy & phenox resins;<br>mfg. of glycerol; cur-<br>ing propellant solvent for<br>cellulose esters &<br>ethers; high wet-<br>strength resins for<br>paper industry | Ew Chem. U.S.A.<br>Shell Chem. Co. - Base<br>Chems.                                                                                                                                                                                                                                                                              | Peeport, Tex.<br>Deer Park, Tex.<br>Norco, La.                                                                                                                                                               | 124.8 (275)<br>72.6 (160)<br>27.2 (60)        | 81.7 (180) -1973                                                                     |
|                 |                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                              | Total =<br>224.7 (495)                        |                                                                                      |

Table A-1. (Continued)

| Chemical      | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                    | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                          | Location(s) <sup>2,3</sup>                                                                                                                                                                                           | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                                               | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Ethanol       | Solvent for resins, fats, oils, fatty acids, nitrocarbons, alkali hydroxides; extractive medium; manufacture of nitrocellulose (especially acetate), talc, talc (hydrate), dyes, synthetic drugs, elastomers, detergents, cleaning solutions, surface coatings, cosmetics, pharmaceuticals, explosives, anti-freeze; beverages; antiseptics; medicine | Commercial Solvents Corp.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Georgia-Pacific Corp. - Chem. Div.<br>Grain Processing Corp.<br>Inland Chem. Corp.<br>National Distillers & Chem. Corp. - Chems. Div. - U.S. Indust. Chems. Co., div.<br>Publicker Indust. Inc.<br>Shell Chem. Co. - Base Chems.<br>Union Carbide Corp. - Chems. & Plastics Div. | Terre Haute, Ind.<br>Longview, Tex.<br>Bellingham, Wash.<br>Muscatine, Iowa<br>Juneau, Wis.<br>Tuscola, Ill.<br>Oreana, La.<br>Philadelphia, Pa.<br>Deer Park, Tex.<br>Texas City, Tex.                              | -<br>78.4 (164)<br>11.0 (26.3)<br>-<br>-<br>196.7 (433.2)<br>-<br>178.0 (394)<br>119.2 (262.6)<br>357.6 (787.7)<br>Total = 938.5 (2067.8) | 862.6 (1900) -1974                                                          |
| Ethyl acetate | General solvent in coatings & plastics; organic synthesis; smokeless powders; pharmaceuticals                                                                                                                                                                                                                                                         | Celanese Corp. - Celanese Chem. Co., div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Monsanto Co. - Monsanto Indust. Chems. Co. - Monsanto Polymers & Petrochems. Co.<br>Publicker Indust. Inc.<br>Union Carbide Corp. - Chems. and Plastics Div.                                                                                                     | Bishop, Tex. ]<br>Pampa, Tex. ]<br>Kingsport, Tex.<br>Longview, Tex.<br>Trenton, Mich.<br>Springfield, Mass.<br>Philadelphia, Pa.<br>Brownsville, Tex.<br>Institute and South Charleston, W. Va.<br>Texas City, Tex. | 27.2 (60)<br>9 (20)<br>9 (20)<br>6.8 (15)<br>9 (20)<br>9 (20)<br>45.4 (100)<br>Total = 115.8 (255)                                        | -                                                                           |
| Ethyl acetate | Organic synthesis; antipyrine; lacquers; dopes; plastics; manufacture of dyes, pharmaceuticals, antimalarials, vitamin B; flavoring                                                                                                                                                                                                                   | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Celanese Inc.                                                                                                                                                                                                                                                                                                 | Kingsport, Tenn.<br>Napleton, Ill.                                                                                                                                                                                   | -<br>-<br>-                                                                                                                               | -                                                                           |

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Table A-1. (Continued)

| Chemical          | Usage <sup>1</sup>                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                            | Location(s) <sup>2,3</sup> | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>2,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Ethyl<br>acrylate | Polymers; acrylic<br>paints; intermediates                                                                                           | Celanese Corp. - Cella-<br>nese Chem. Co., div.                           | Clear Lake, Tex.           | -                                              | 75 (165.2)-1968                                                             |
|                   |                                                                                                                                      | Dow Badische Co.                                                          | Pampa, Tex.                | -                                              |                                                                             |
|                   |                                                                                                                                      | Rohm & Haas Co. - Rohm<br>& Haas Texas Inc.,<br>subsidi.                  | Freeport, Tex.             | -                                              |                                                                             |
|                   |                                                                                                                                      | Union Carbide Corp. -<br>Chems. & Plastics Div.                           | Deer Park, Tex.            | -                                              |                                                                             |
| Ethyl-<br>amine   | Dye intermediates;<br>solvent extraction;<br>petroleum refining;<br>stabilizer for rubber<br>latex; detergents;<br>organic synthesis | Air Products & Chems.,<br>Pennwalt Corp. -<br>Chem. Div.                  | Taft, La.                  | -                                              | 25.2 (55.5) -1972                                                           |
|                   |                                                                                                                                      | Union Carbide Corp. -<br>Chems. & Plastics Div.                           | Pensacola, Fla.            | -                                              |                                                                             |
| Ethyl<br>benzene  | Intermediate in produc-<br>tion of styrene,<br>solvent                                                                               | Virginia Chems. Inc. -<br>Indust. Chems. Dept.                            | Wyandotte, Mich.           | -                                              |                                                                             |
|                   |                                                                                                                                      | American Petrofina,<br>Inc. - Coaden Oil &<br>Chem. Co., subsidi.         | Taft, La.                  | -                                              |                                                                             |
|                   |                                                                                                                                      | ARCO/Polymers, Inc.                                                       | Fort Smith, Va.            | -                                              |                                                                             |
|                   |                                                                                                                                      | The Charter Co. - subsidi.,<br>Charter International<br>Oil Co., subsidi. | Big Spring, Tex.           | 61.3 (135)                                     | 2588 (5700) -1973                                                           |
|                   |                                                                                                                                      | Commonwealth Oil Refin-<br>ing Co., Inc. - Styro-<br>chem Corp., subsidi. | Houston, Tex.              | 45.4 (100)                                     |                                                                             |
|                   |                                                                                                                                      | Cos-Mar, Inc.                                                             | Port Arthur, Tex.          | 245.2 (540)                                    |                                                                             |
|                   |                                                                                                                                      | Dow Chem. U.S.A.                                                          | Houston, Tex.              | 15.9 (35)                                      |                                                                             |
|                   |                                                                                                                                      | El Paso Natural Gas<br>Co., El Paso Products<br>Co., subsidi.             | Pemulas, P. R.             | 40.9 (90)                                      |                                                                             |
|                   |                                                                                                                                      | Postor Grant Co., Inc.                                                    | Carville, La.              | 326.9 (720)                                    |                                                                             |
|                   |                                                                                                                                      | Guif Oil Corp. -<br>Guif Oil Chems. Co.,<br>div. - Petrochems.<br>Div.    | Freeport, Tex.             | 846.7 (1865)                                   |                                                                             |
|                   |                                                                                                                                      |                                                                           | Midland, Mich.             | 158.9 (350)                                    |                                                                             |
|                   |                                                                                                                                      |                                                                           | Odessa, Tex.               | 124.8 (275)                                    |                                                                             |
|                   |                                                                                                                                      |                                                                           | Fatou, Rouge, La.          | 440.4 (970)                                    |                                                                             |
|                   |                                                                                                                                      |                                                                           | Welcome, La.               | 256.5 (565)                                    |                                                                             |



Table A-1. (Continued)

| Chemical                    | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                              | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                     | Location(s) <sup>2,3</sup>                                                         | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                                                         | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Ethyl<br>benzene<br>(cont.) | (See previous page)                                                                                                                                                                                                                                                                                                                             | Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.<br>Phillips Petroleum Co. -<br>Petrochem. & Supply Div.<br>Standard Oil Co. (Ind.)<br>Amoco Chem. Corp.,<br>subsidi.<br>Sun Oil Co. - Sun Oil<br>Co. of Pa., subsidi. -<br>Sunbide Refining Co.,<br>subsidi.<br>Tenneco Inc. - Tenneco<br>Oil Co., div.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. | Chocolate Bayou,<br>Tex.<br>Texas City, Tex.<br>Phillips, Tex.<br>Texas City, Tex. | 667.4 (1470)<br>-<br>429.0 (945)<br>47.7 (106)<br>11.8 (26)<br>154.4 (340)<br>Total =<br>3873.1 (8531) | -                                                                                                  |
| Ethyl<br>bromide            | Organic synthesis;<br>medicine (anesthetic);<br>refrigerant; solvent;<br>grain & fruit<br>fumigant                                                                                                                                                                                                                                              | Dow Chem. U.S.A.<br>Great Lakes Chem. Corp.<br>Northwest Indust., Inc. -<br>Michigan Chem. Corp.,<br>subsidi.<br>American Polymers, Inc.<br>Hercules Inc. - Coatings<br>& Specialty Products<br>Dept.                                                                                                                                                              | Midland, Mich.<br>El Dorado, Ark.<br>St. Louis, Mich.<br>Patterson, N. J.          | -<br>-<br>-<br>-                                                                                       | -<br>-<br>-<br>2.9 (6.5) -1973                                                                     |
| Ethyl<br>cellulose          | Hot-melt adhesives &<br>coatings for cables;<br>paper, textiles, etc.;<br>extrusion wire insula-<br>tion; protective coat-<br>ings; pigment-grind-<br>ing base; toughening<br>agent for plastics;<br>printing inks; molding<br>powders; proximity<br>fuses; vitamin prepara-<br>tion; casing for rocket<br>propellants; food &<br>feed additive |                                                                                                                                                                                                                                                                                                                                                                    |                                                                                    |                                                                                                        |                                                                                                    |

Table A-1. (Continued)

| Chemical            | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                 | Manufacturer(s) <sup>2,3</sup>                                                     | Location(s) <sup>2,3</sup>                                           | 1975 capacity <sup>2</sup><br>MM kg (MM lb)              | Total <sup>1,2,3</sup> production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------------------------|
| Ethyl chloride      | Manufacture of tetra-ethyl lead & ethyl-cellulose; anesthetics; organic synthesis; refrigeration; analytical reagent; solvent for phosphorus, sulfur, fats, oils, resins & waxes; insecticides                                                                                                                                                                                                     | Dow Chem. U.S.A.                                                                   | Freeport, Tex.                                                       | 34 (75)                                                  | 299.7 (660.1) -1973                                                        |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | Ethyl Corp.                                                                        | Baton Rouge, La.<br>Pasadena, Tex.<br>Lake Charles, La.              | 95.3 (210)<br>68.1 (150)<br>54.5 (120)                   |                                                                            |
| Ethyl chloroacetate | Solvent; organic synthesis; military poison gas; vat dyes                                                                                                                                                                                                                                                                                                                                          | PPG Indust., Inc. - Chem. Div. - Indust. Chem. Div.                                | Deer Park, Tex.                                                      | 38.6 (85)                                                | Total =<br>340.5 (750)                                                     |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | Shell Chem. Co. - Base Chems.                                                      | Carson, Calif.                                                       | 50 (110)                                                 |                                                                            |
| Ethyl cyanoacetate  | Organic synthesis; pharmaceuticals; dyes                                                                                                                                                                                                                                                                                                                                                           | Stauffer Chem. Co. - Plastics Div. - Polymers West                                 | Midland, Mich.                                                       | -                                                        | -                                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | Dow Chem. U.S.A.                                                                   | Stony Point, N. Y.                                                   | -                                                        |                                                                            |
| Ethylene            | Manufacture of ethyl alcohol, ethylene glycol, ethylene dichloride, aluminum alkyls, vinyl chloride, ethyl chloride, ethylene oxide, ethylene chlorohydrin, acetaldehyde, linear alcohols, polystyrene, styrene, polyethylene, polyvinyl chloride, SRP, polyester resins tri-chloroethylene, etc.; refrigerant; cryogenic research; agricultural chemical; welding & cutting of metals; anesthetic | Monsanto Co. - Monsanto Indust. Chems. Co.                                         | St. Louis, Mo.                                                       | -                                                        | -                                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | Kay-Fries Chem. Inc. - Loraz Inc.                                                  | Stony Point, N. Y.<br>Mapleton, Ill.                                 | -<br>-                                                   |                                                                            |
| Ethylene            | Manufacture of ethyl alcohol, ethylene glycol, ethylene dichloride, aluminum alkyls, vinyl chloride, ethyl chloride, ethylene oxide, ethylene chlorohydrin, acetaldehyde, linear alcohols, polystyrene, styrene, polyethylene, polyvinyl chloride, SRP, polyester resins tri-chloroethylene, etc.; refrigerant; cryogenic research; agricultural chemical; welding & cutting of metals; anesthetic | Allied Chem. Corp. - Union Texas Petroleum Div.                                    | Geismar, La.<br>Houston, Tex.                                        | 340.5 (750)<br>227 (500)                                 | 10,710.0 (23,590) -1974                                                    |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | AMCO/Polymers, Inc. - Atlantic Richfield Co. - ARCO Chem. Co., div. Chemplex Co.   | Wilmington, Calif.                                                   | 45.4 (100)                                               |                                                                            |
| Ethylene            | Manufacture of ethyl alcohol, ethylene glycol, ethylene dichloride, aluminum alkyls, vinyl chloride, ethyl chloride, ethylene oxide, ethylene chlorohydrin, acetaldehyde, linear alcohols, polystyrene, styrene, polyethylene, polyvinyl chloride, SRP, polyester resins tri-chloroethylene, etc.; refrigerant; cryogenic research; agricultural chemical; welding & cutting of metals; anesthetic | Cities Service Co., Inc. - North American Petroleum Group                          | Clinton, Iowa<br>Lake Charles, La.                                   | 227 (500)<br>426.8 (940)                                 | -                                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | Continental Oil Co. - Conoco Chems.                                                | Westlake, La.                                                        | 295.1 (650)                                              |                                                                            |
| Ethylene            | Manufacture of ethyl alcohol, ethylene glycol, ethylene dichloride, aluminum alkyls, vinyl chloride, ethyl chloride, ethylene oxide, ethylene chlorohydrin, acetaldehyde, linear alcohols, polystyrene, styrene, polyethylene, polyvinyl chloride, SRP, polyester resins tri-chloroethylene, etc.; refrigerant; cryogenic research; agricultural chemical; welding & cutting of metals; anesthetic | Dow Chem. U.S.A.                                                                   | Bay City, Mich.<br>Freeport, Tex.<br>Plaquemine, La.<br>Orange, Tex. | 77.2 (170)<br>1134 (2500)<br>490.4 (1100)<br>374.5 (825) | -                                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    | E. I. du Pont de Nemours & Co., Inc. - Plastics Dept.                              | Longview, Tex.                                                       | 361.1 (800)                                              |                                                                            |
| Ethylene            | Manufacture of ethyl alcohol, ethylene glycol, ethylene dichloride, aluminum alkyls, vinyl chloride, ethyl chloride, ethylene oxide, ethylene chlorohydrin, acetaldehyde, linear alcohols, polystyrene, styrene, polyethylene, polyvinyl chloride, SRP, polyester resins tri-chloroethylene, etc.; refrigerant; cryogenic research; agricultural chemical; welding & cutting of metals; anesthetic | Eastman Kodak Co. - Eastman Chem. Products, Inc. - subd. - Texas Eastman Co., div. |                                                                      |                                                          | -                                                                          |
|                     |                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                    |                                                                      |                                                          |                                                                            |

Table A-1. (Continued)

| Chemical<br>(cont'd) | Usage <sup>1</sup><br>(See previous page) | Manufacturer(s) <sup>2,3</sup>                                                                                              | Location(s) <sup>2,3</sup>                                                       | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                  | Totals <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|----------------------|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Ethylene<br>(cont'd) |                                           | El Paso Natural Gas Co. -<br>subsidi.                                                                                       | Odessa, Tex.                                                                     | 234.7 (517)                                                     |                                                                                                     |
|                      |                                           | Exxon Corp. - Exxon<br>Chem. Co., div. -<br>Exxon Chem. Co. U.S.A.                                                          | Baton Rouge, La.<br>Baton Rouge, Tex.                                            | 771.8 (1700)<br>31.8 (70)                                       |                                                                                                     |
|                      |                                           | The E. F. Woodrich Co. -<br>E. F. Woodrich Chem. Co.,<br>div.                                                               | Calvert City, Ky.                                                                | 158.9 (350)                                                     |                                                                                                     |
|                      |                                           | Gulf Oil Corp. - Gulf<br>Oil Chems. Co., div. -<br>Petrochems. Div.                                                         | Cedar Bayou, Tex.<br>Port Arthur, Tex.                                           | 190.7 (420)<br>522.1 (1150)                                     |                                                                                                     |
|                      |                                           | Mobil Oil Corp. - Mobil<br>Chem. Co., div. -<br>Petrochems. Div.                                                            | Beaumont, Tex.                                                                   | 213.4 (470)                                                     |                                                                                                     |
|                      |                                           | Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.                                                                    | Chocolate Bayou,<br>Texas City, Tex.                                             | 295.1 (650)<br>68.1 (150)                                       |                                                                                                     |
|                      |                                           | National Distillers &<br>Chem. Corp. - Chems.<br>Div. - U.S. Indust.<br>Chems. Co., div.                                    | Tuscola, Ill.                                                                    | 158.9 (350)                                                     |                                                                                                     |
|                      |                                           | Northern Natural Gas Co. -<br>Northern Petrochem. Co.,<br>subsidi., Polymers Div.<br>Olin Corp. - Designed<br>Products Div. | Morris, Ill.<br>Brandenburg, Ky.                                                 | 363.2 (800)<br>54.5 (120)                                       |                                                                                                     |
|                      |                                           | Petro Gas Producing Co.<br>Phillips Petroleum Co.<br>Puerto Rico Olefins Co.<br>Shell Chem. Co. - Base<br>Chems.            | Groves, Tex.<br>Sweeny, Tex.<br>Fenuelas, P. R.<br>Deer Park, Tex.<br>Morco, La. | 9 (20)<br>517.6 (1140)<br>454 (1000)<br>681 (1500)<br>250 (550) |                                                                                                     |
|                      |                                           | Standard Oil Co. (Ind.) -<br>Amoco Chems. Corp.,<br>subsidi.                                                                | Chocolate Bayou,<br>Claymont, Del.                                               | 454 (1000)<br>102 (225)                                         |                                                                                                     |
|                      |                                           | Sunolin Chem. Co.                                                                                                           |                                                                                  |                                                                 |                                                                                                     |

Table A-1. (Continued)

| Chemical                      | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                       | Manufacturer(s) <sup>2,3</sup>                                      | Location(s) <sup>2,3</sup>                                                           | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb.)                         | Total <sup>3,4</sup><br>production<br>MM kg (MM lb.)<br>for year of estimate |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Ethylene<br>(cont'd)          | (See previous page)                                                                                                                                                                                                                                                                                                                                                                      |                                                                     |                                                                                      |                                                                         | (See previous page)                                                          |
|                               |                                                                                                                                                                                                                                                                                                                                                                                          | Texaco Inc. - Jefferson<br>Chem. Co., Inc., subsid.                 | Port Neches, Tex.                                                                    | 238.3 (525)                                                             |                                                                              |
|                               |                                                                                                                                                                                                                                                                                                                                                                                          | Union Carbide Corp. -<br>Chems. & Plastics Div.                     | Seadrift, Tex.<br>Taft, La.<br>Texas City, Tex.<br>Torrance, Calif.<br>Whiting, Ind. | 549.3 (1210)<br>186.1 (410)<br>726.4 (1600)<br>77.2 (170)<br>68.1 (150) |                                                                              |
|                               |                                                                                                                                                                                                                                                                                                                                                                                          | Union Carbide Caribe,<br>Inc., subsid.                              | Panuelas, P. R.                                                                      | 351.8 (775)                                                             |                                                                              |
|                               |                                                                                                                                                                                                                                                                                                                                                                                          |                                                                     |                                                                                      | Total =                                                                 |                                                                              |
|                               |                                                                                                                                                                                                                                                                                                                                                                                          |                                                                     |                                                                                      | 11,285                                                                  | 24,957                                                                       |
| Ethylene<br>carbonate         | Solvent for many<br>polymers & resins;<br>solvent extraction;<br>synthesis of pharma-<br>ceuticals, rubber<br>chemicals, textile<br>finishing agents                                                                                                                                                                                                                                     | Texaco Inc. - Jefferson<br>Chem. Co., Inc., subsid.                 | Conroe, Tex.                                                                         | -                                                                       | -                                                                            |
| Ethylene<br>chloro-<br>hydrin | Solvent for cellulose<br>acetate, ethylcellulose;<br>introduction of hydro-<br>ethylated cellulose<br>synthesis; to acti-<br>vate sprouting of dor-<br>mant potatoes; mfg.<br>of ethylene glycol                                                                                                                                                                                         | Union Carbide Corp. -<br>Chems. & Plastics Div.                     | Institute & South<br>Charleston, W. Va.                                              | -                                                                       | -                                                                            |
| Ethylene<br>diamine           | Solvent for albumin<br>& fibrin; medicine;<br>neutralizing oils;<br>stabilizing rubber<br>latex; corrosion in-<br>hibitor in antifreeze<br>solutions; textile<br>lubricants; dyes; rubber<br>accelerators; making<br>ethylenediamine nitrate,<br>chlorate, and EDTA; de-<br>hairing skins; emulsifier;<br>organic synthesis; poly-<br>amide resin adhesives;<br>heat-sensitive adhesives | Pow Chem. U.S.A.<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Preepart, Tex.<br>Taft, La.<br>Texas City, Tex.                                      | 13.6 (30)<br>16.3 (36)<br>10.9 (24)<br>Total =<br>40.9 (90)             | 30 (66) -1974                                                                |

Table A-1. (Continued)

| Chemical               | Usage <sup>1</sup>                                                                                                                                                                                                                                                       | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                     | Location(s) <sup>2,3</sup>                                                                                                                                                 | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                                                                                    | Total <sup>2,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Ethylene<br>dibromide  | Scavenger for lead in<br>gasoline; grain & fruit<br>fungicide; general sol-<br>vent; waterproofer; dis-<br>infectant; organic<br>synthesis; insecticide;<br>medicine                                                                                                     | Dow Chem. U.S.A.                                                                                                                                                                                                                                   | Magnolia, Ark.<br>Midland, Mich.                                                                                                                                           | -                                                                                                                                 | 152.1 (335) -1973                                                           |
|                        |                                                                                                                                                                                                                                                                          | Ethyl Corp. - Brine<br>Products Div.<br>Great Lakes Chem. Corp.<br>Northwest Indust.,<br>Inc. - Michigan Chem.<br>Corp., subsid.<br>PPG Indust., Inc. -<br>Chem. Div. - Houston<br>Chem. Co., div.                                                 | Magnolia, Ark.<br>El Dorado, Ark.<br>El Dorado, Ark.<br>Beaumont, Tex.                                                                                                     | -                                                                                                                                 |                                                                             |
| Ethylene<br>dichloride | Vinyl chloride; chlori-<br>nated solvent intermedi-<br>ate; coupling agent in<br>antiknock gasoline; paint,<br>varnish, finish<br>removers; metal degreas-<br>ing; soap & scouring<br>compounds; wetting &<br>penetrating agents;<br>organic synthesis; ore<br>flotation | Allied Chem. Corp. -<br>Indust. Chems. Div.<br>Continental Oil Co. -<br>Conoco Chems.<br>Diamond Shamrock Corp. -<br>Diamond Shamrock Chem.<br>Co., Electro Chems. Div.<br>Dow Chem. U.S.A.                                                        | Eaton Rouge, La.<br>Westlake, La.<br>Deer Park, Tex.<br>Freeport, Tex.<br>Oyster Creek, Tex.<br>Plaquemine, La.<br>Baton Rouge, La.<br>Pasadena, Tex.<br>Calvert City, Ky. | 295.1 (650)<br>454 (1000)<br>118 (260)<br>530.2 (1300)<br>499.4 (1100)<br>526.6 (1160)<br>249.7 (550)<br>118 (260)<br>408.6 (900) | 3505 (7,720)-1974                                                           |
|                        |                                                                                                                                                                                                                                                                          | Ethyl Corp.<br>The B. F. Goodrich Co. -<br>Co., div.<br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div. - PPG<br>PPG Indust., (Caribe)<br>Shell Chem. Co. -<br>Base Chems.<br>Stauffer Chem. Co. -<br>Plastics Div. - Poly-<br>mers West | Lake Charles, La.<br>Guayanilla, P. R.<br>Deer Park, Tex.<br>Norco, La.<br>Carson, Calif.                                                                                  | 454 (1000)<br>370.1 (836)<br>544.8 (1200)<br>528.9 (1165)<br>136.2 (300)                                                          |                                                                             |

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Table A-1. (Continued)

| Chemical                           | Use <sup>1</sup><br>(See previous page)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                   | 1975<br>capacity,<br>MM kg (MM lb)<br>for year of estimate                                                                                                                        | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Ethylene<br>dichloride<br>(cont'd) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Texaso Inc. - Jefferson<br>Chem. Co., Inc., subsid.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Port Neches, Tex.                                                                                                                                                                                                                                            | 31.8 (70)                                                                                                                                                                         | (See previous page)                                                         |
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Taft, La.                                                                                                                                                                                                                                                    | 68.1 (150)                                                                                                                                                                        |                                                                             |
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Vulcan Materials Co. -<br>Chem. Div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Texas City, Tex.                                                                                                                                                                                                                                             | 68.1 (150)                                                                                                                                                                        |                                                                             |
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Geismar, La.                                                                                                                                                                                                                                                 | 109 (240)                                                                                                                                                                         |                                                                             |
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                              | Total =<br>5,573.7 (12,200)                                                                                                                                                       |                                                                             |
| Ethylene<br>glycol                 | Coolant & antifreeze;<br>asphalt-emulsion paints;<br>heat-transfer agent in<br>refrigeration & electron<br>tubes; low-pressure lam-<br>nates; brake fluids;<br>glycol diacetate; poly-<br>ester filters & films;<br>low-temperature fluids;<br>lubricating oil additives;<br>various purposes: sol-<br>vent mixtures for cel-<br>lulose esters & ethers,<br>especially cellophane;<br>cosmetics (up to 5%);<br>lacquers; alkylid resins;<br>printing inks; wood<br>stains; adhesives;<br>leather dyeing; tex-<br>tile processing; tobac-<br>co ingredient of<br>deicing fluid for<br>airport runways | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>SASR Wyandotte Corp. -<br>Indust. Chems. Group<br>Calcasieu Chem. Corp.<br>Celanese Corp. - Cella-<br>nese Chem. Co., div.<br>Dixie Chem. Co.<br>Dow Chem. U.S.A.<br>Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. - Texas<br>Eastman Co., div.<br>ICI United States Inc. -<br>Specialty Chems. Div.<br>Northern Natural Gas Co.,<br>Northern Petroleum Co.,<br>subsid. - Polymers Div.<br>Olin Corp. - Designed<br>Products Div.<br>PPG Indust., Inc. -<br>Chem. Div. - Houston<br>Chem. Co., div. -<br>PPG Indust. (Caribe)<br>Shell Chem. Co. - Base<br>Chems. | Orange, Tex.<br>Geismar, La.<br>Lake Charles, La.<br>Clear Lake, Tex.<br>Bayport, Tex.<br>Freeport, Tex.<br>Piaquemine, La.<br>Longview, Tex.<br>New Castle, Del.<br>Morris, Ill.<br>Brandenburg, Ky.<br>Beaumont, Tex.<br>Guayanilla, P. R.<br>Geismar, La. | 19.2 (40)<br>65.1 (150)<br>81.7 (180)<br>136.2 (300)<br>-<br>56.8 (125)<br>199.8 (440)<br>22.7 (50)<br>4.5 (10)<br>236.2 (520)<br>22.7<br>86.3 (190)<br>181.6 (400)<br>45.4 (100) | 1,398 (3,080)-1974                                                          |

Table A-1. (Continued)

| Chemical                 | Usage <sup>1</sup>                                                                                                                                | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                 | Location(s) <sup>2,3</sup>                                                         | 1975<br>capacity,<br>MM kg (MM lb.)<br>for year of estimate | Total <sup>3,3</sup><br>production<br>MM kg (MM lb.)<br>for year of estimate |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------------------------|
| Ethylene glycol (cont'd) | (See previous page)                                                                                                                               |                                                                                                                                                                                |                                                                                    |                                                             |                                                                              |
|                          | Solvent for cellulose esters & ethers; preins; lacquers; priming inks; perfume fixative; non-discoloring plasticizer for ethyl & benzyl cellulose | Texasco Inc. - Jefferson Chem. Co., Inc., subd.<br>Union Carb. Corp. - Chem. Products Div.<br>Union Carbide Corp. - Chem. & Plastics Div.<br>Union Carbide Caribe, Inc., subd. | Port Neches, Tex.<br>Dover, Ohio<br>Seadrift, Tex.<br>Tart, La.<br>Penuelas, P. R. | 163.4 (360)<br>-<br>395 (870)<br>136.2 (300)<br>286 (630)   | (See previous page)                                                          |
|                          |                                                                                                                                                   | Eastman Kodak Co. - Eastman Chem. Products, Inc., subd. - Tenn. Eastman Co., div.<br>Union Carbide Corp. - Chem. & Plastics Div.                                               | Kingsport, Tenn.<br>Institute & South Charleston, W. Va.                           | -<br>-                                                      | Total =<br>2,009 (4425)                                                      |
|                          | High-boiling inert solvent; specialized solvent & extraction applications                                                                         | Union Carbide Corp. - Chem. & Plastics Div.                                                                                                                                    | Institute & South Charleston, W. Va.                                               | -                                                           | -                                                                            |
|                          | Organic synthesis (reaction medium); solvent & diluent for detergents                                                                             | -                                                                                                                                                                              | -                                                                                  | -                                                           | -                                                                            |
|                          | Solvent                                                                                                                                           | The Ansel Co. - Chem. Div.                                                                                                                                                     | Marinette, Wisc.                                                                   | -                                                           | -                                                                            |
|                          | Solvent for nitrocellulose, cellulose acetate, camphor                                                                                            | Jyco Chem., Inc.<br>Schroeder Brothers, Inc.                                                                                                                                   | Williamsport, Pa.<br>Clifton, N. J.                                                | -<br>-                                                      | -                                                                            |

Table A-1. (Continued)

| Chemical                                 | Usage                                                                                                                                                                                                                                                                                                      | Manufacturers                                                                                                                                                                                                                                                                                                      | Location(s)                                                                                                                                                               | 1975 capacity <sup>2</sup><br>MM Kf (MM lb.) | Total <sup>1</sup> production<br>MM Kf (MM lb.)<br>for year of estimate |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------------------------------------------------------------|
| Ethylene glycol mono-butyl ether         | Solvent for nitrocellulose resins; spray lacquers; quick-drying lacquers; varnishes; enamels; dry-cleaning compounds; varnish removers; textile (preventing spotting in printing and dyeing); mutual solvent for "soluble" mineral oils & to hold soap in solution & to improve the emulsifying properties | Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>Shell Chem. Co. - Base Chems.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.                             | Midland, Mich.<br>Longview, Tex.<br><br>Brandenburg, Ky.<br>Geismar, La.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va.<br>Kingsport, Tenn.                 | -<br>-<br>-<br>-<br>-<br>-                   | 54.6 (120) -1972                                                        |
| Ethylene glycol mono-butyl ether acetate | High-boiling solvent for nitrocellulose lacquers; epoxy resins; multicolor lacquers; film coalescing aid for polyvinyl acetate latex                                                                                                                                                                       | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                                                                                                                                             | Midland, Mich.<br>Longview, Tex.<br>Brandenburg, Ky.                                                                                                                      | -<br>-<br>-                                  | 77.2 (170) -1972                                                        |
| Ethylene glycol mono-ethyl ether         | Solvent for nitrocellulose; natural & synthetic resins; mutual solvent for formalin of soluble oils; lacquers & lacquer thinners; dyeing & printing textiles; varnish removers; cleaning solutions; leather; anti-icing additive for aviation fuels.                                                       | Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Olin Corp. - Designed Products Div.                                                                                                                                                                  | Midland, Mich.<br>Longview, Tex.<br>Brandenburg, Ky.                                                                                                                      | -<br>-<br>-                                  | 54.6 (120) -1972                                                        |
| Ethylene glycol mono-ethyl ether acetate | Solvent for nitrocellulose; oils; resins; lacquers; varnishes; wood stains; textiles; leather                                                                                                                                                                                                              | Shell Chem. Co. - Base Chems.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>Union Carbide Corp. - Chems. & Plastics Div. | Geismar, La.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va.<br>Seadrift, Tex.<br>Longview, Tex.<br>Brandenburg, Ky.<br>Institute & South Charleston, W. Va. | -<br>-<br>-<br>-<br>-<br>-<br>-              | -                                                                       |



Table A-1. (Continued)

| Chemical                          | Usage                                                                                                                                                                                                                                                | Manufacturer(s)                                                                                                                                                                                                                                                        | Location(s)                                                                                                      | 1975 capacity?<br>MM KG (MM LB) | Total 1975<br>Production<br>MM KG (MM LB)<br>for year of estimate |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------|-------------------------------------------------------------------|
| Ethylene glycol mono-benzyl ether | High-boiling solvent                                                                                                                                                                                                                                 | -                                                                                                                                                                                                                                                                      | -                                                                                                                | -                               | -                                                                 |
| Ethylene glycol mono-benzyl ether | Solvent for nitrocellulose, cellulose acetate, alcohol-soluble dyes, natural & synthetic resins; solvent mixtures; lacquers; enamels; varnishes; leather; perfume fixative; wood stains; sealing moisture-proof cellulose; jet fuel deicing additive | Tex. Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas<br>Eastman Co., div.<br>Olin Corp. - Designed Products Div.<br>Fierve Chem. Co.<br>FPI Indust., Inc. - Chem. Div. - Houston<br>Chem. Co., div.<br>Shell Chem. Co.<br>East Chem. | Midland, Mich.<br>Longview, Tex.<br><br>Brandenburg, Ky.<br>Rockford, Ill.<br>Beaumont, Tex.<br><br>Geismar, La. | -<br>-<br>-<br>-<br>-<br>-<br>- | 43 (95) -1972                                                     |
| Ethylene glycol mono-benzyl ether | Solvent for nitrocellulose, cellulose acetate, various gums, resins, waxes, oils; textile printing; photographic film; lacquers; dopes                                                                                                               | Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chem. & Plastics Div.<br><br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Union Carbide Corp. - Chem. & Plastics Div.                           | Port Neches, Tex.<br>Institute & South Charleston, W. Va. Taft, La.<br><br>Kingsport, Tenn.                      | -<br>-<br>-<br>-                | -                                                                 |
| Ethylene glycol mono-octyl ether  | Solvent for cellulose esters; plasticizer                                                                                                                                                                                                            | -                                                                                                                                                                                                                                                                      | -                                                                                                                | -                               | -                                                                 |

Table A-1. (Continued)

| Chemical                          | Usage                                                                                                                                                                             | Manufacturer(s) 2,3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Location(s) 2,3                                                                                                                                                                                                                                                                                                     | Size capacity, 2 MM cu (MM cu)                                                                                                                                                                                                       | Total's production MM cu (MM cu) for year of estimate |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Ethylene glycol mono-phenyl ether | Solvent for cellulose acetate, dye inks, resins; perfume & soap fixative; bacterial agent; organic synthesis of plasticizers, semiconductors, perfume materials & pharmaceuticals | Dow Chem. U.S.A.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Midland, Mich.                                                                                                                                                                                                                                                                                                      | -                                                                                                                                                                                                                                    | -                                                     |
| Ethylene monobromide              | -                                                                                                                                                                                 | Olin Corp. - Designed Products Inc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Brandenburg, Ky.                                                                                                                                                                                                                                                                                                    | -                                                                                                                                                                                                                                    | -                                                     |
| Ethylene oxide                    | Manufacture of ethylene glycol & higher glycols; polyester fiber & film; surfactants; acrylonitrile; ethanolamines; petroleum demulsifier; fumigant; rocket propellant            | Allied Chem. Corp. - Specialty Chems. Div.<br>BASF Wyandotte Corp. - Indust. Chems. Group<br>Calcasieu Chem. Corp.<br>Celanese Corp. - Celanese Chem. Co., div.<br>Dow Chem. U.S.A.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subd., Texas<br>Eastman Co., div.<br>Northern Natural Gas Co. - Northern Petroleum Co., subd. - Polymers Div.<br>Olin Corp. - Designed Products Div.<br>PPG Indust., Inc. - Chem. Div. - Houston Chem. Co., div.<br>PPG Indust. (Carbide) Shell Chem. Co. - Base Chems.<br>SunOlin Chem. Co.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subd.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Union Carbide Carbide, Inc., subd. | Orange, Tex.<br>Geismar, La.<br>Lake Charles, La.<br>Clear Lake, Tex.<br>Freeport, Tex.<br>Plaquemine, La.<br>Longview, Tex.<br>Morris, Ill.<br>Brandenburg, Ky.<br>Beaumont, Tex.<br>Guyanilla, F. R.<br>Geismar, La.<br>Claymont, Del.<br>Fort Worth, Tex.<br>Seadrift, Tex.<br>Taft, La.<br>Ponchartraine, F. R. | 22.7 (50)<br>100 (220)<br>74.0 (165)<br>135.2 (300)<br>90.8 (200)<br>181.0 (400)<br>18.2 (40)<br>90.8 (200)<br>50 (110)<br>38.6 (85)<br>136.0 (300)<br>136.2 (300)<br>43.1 (90)<br>22.7 (50)<br>36.7 (81)<br>284.8 (630)<br>100 (60) | 1,798 (3,960) -1974                                   |
| Total =                           |                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                     | 2,105.1 (4,844)                                                                                                                                                                                                                      |                                                       |

Table A-1. (Continued)

| Chemical                 | Use <sup>1</sup>                                                                                                                                                                                                                                                          | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                       | Location(s) <sup>2,3</sup>                                                                                                                                                                                  | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                 | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------|
| Ethyl ether              | Manufacture of ethylene & other chemical synthesis; industrial solvent (smokeless powder); analytical chemistry; anesthetic; perfumery; extractant; alcohol denaturant                                                                                                    | Hercules Inc. - Coatings & Specialty Products Dept.<br>Mallinckrodt, Inc. - Medicinal Div.<br>National Distillers & Chem. Corp. - Chems. Div.<br>Publicker Indust., Inc.<br>Squibb Corp. - E. R. Squibb & Sons, Inc., subsid. - U.S. Pharmaceutical Co. - Operations<br>Union Carbide Corp. - Chems. & Plastics Div.                 | Hopewell, Va.<br>St. Louis, Mo.<br>Tuscola, Ill.<br>Philadelphia, Pa.<br>New Brunswick,                                                                                                                     | 1 (2)<br>1 (2)<br>18.2 (40)<br>4.5 (10)<br>1 (2)            | 27.2 (60) -1974                                                             |
| 2-Ethyl hexanol          | Plasticizer for PVC resins; defoaming agent; wetting agent; organic synthesis; solvent mixtures for nitrocellulose, paints, lacquers, baking finishes; penetrant for mercerizing cotton; textile finishing compounds; plasticizers; lubricants; photography; dry cleaning | Dow Badische Co.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Texas Eastman Co., div.<br>W. R. Grace & Co. - Natco Group - Natco Chem. Div.<br>Oxochem Enterprise<br>Shell Chem. Co. - Base Chems.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>Union Carbide Caribe, Inc., subsid.<br>Kay-Fries Chem., Inc. | Institute & South Charleston, W. Va.<br>Texas City, Texas<br>Freeport, Tex.<br>Longview, Tex.<br>Fords, N. J.<br>Penuelas, F. R. Deer Park, Tex.<br>Seadrift, Tex.<br>Penuelas, F. R.<br>Stony Point, N. Y. | 6.8 (15)<br>Total = 32.2 (71)<br>-<br>-<br>-<br>-<br>-<br>- | -                                                                           |
| Ethyl orthoformate       | Intermediate                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                             |                                                             |                                                                             |
| Ethyl oxalate            | Solvent for cellulose & ethers; many natural & synthetic resins; radio tubes; electrode; filling lacquers; dye intermediate; pharmaceuticals; perfume preparations; organic synthesis                                                                                     | PMC Corp. - Chem. Group - Indust. Chem. Div.                                                                                                                                                                                                                                                                                         | Baltimore, Md.                                                                                                                                                                                              | -                                                           | -                                                                           |
| Ethyl sodium oxalacetate | Dyes; synthesis                                                                                                                                                                                                                                                           | PMC Corp. - Chem. Group - Indust. Chem. Div.                                                                                                                                                                                                                                                                                         | Baltimore, Md.                                                                                                                                                                                              | -                                                           | -                                                                           |

1975  
production  
MM KG (MM lb)  
capacity,<sup>2</sup>  
MM KG (MM lb)

6-906

Table A-1. (Continued)

| Chemical     | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1976 capacity <sup>2</sup><br>MM lb. (MM lb.)                                                                                                                                                                                                                                                                                                                                                                                                                          | 1976 production<br>MM lb. (MM lb.) | Total <sup>2,3</sup><br>for year of estimate |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|----------------------------------------------|
| Formaldehyde | Urea & Melamine resins; phenolic resins; ethylene glycol; pentaerythritol; hexamethylenetetramine; fertilizers; acetals; other chemicals; dyes; medicine (disinfectant, germicide); enamming fluids; preservative; hardening agent; reducing agent; as intermediate; in intermediate; as intermediate; corrosion inhibitor in oil wells; durable-press treatment of textile fabrics; possible condensation to sugars & other carbohydrates for food use (experimental) | Allied Chem. Corp. - Specialty Chems. Div.<br>Borden Inc. - Borden Chem. Div. - Adhesives & Chems., Div., East<br>Adhesives & Chems., Div., West<br>Celanese Corp. - Celanese Chem. Co., div.<br>Commercial Solvents Corp.<br>E. I. du Pont de Nemours & Co., Inc. - Biochems. Dept.<br>Indust. Chems. Dept.<br>GAF Corp. - Chem. Div.<br>Georgia-Pacific Corp. - Chem. Div.<br>Gulf Oil Corp. - Gulf Oil Chems. Co., div. - Indust. & Specialty Chems. Div.<br>Hercules Inc. - Synthetics Dept.<br>Monsanto Co. - Monsanto Polymers & Petrochems. Co. | South Point, Ohio<br>Demopolis, Ala.<br>Irving, Tex.<br>Lafayetteville, N. C.<br>Louisville, Ky.<br>Sheboygan, Wis.<br>Fremont, Calif.<br>Kent, Wash.<br>La Grande, Ore.<br>Mankato, Minn.<br>Springfield, Ore.<br>Bishop, Tex.<br>Newark, N. J.<br>Rock Hill, S. C.<br>Seiple, Pa.<br>Belle, W. Va.<br>La Porte, Tex.<br>Healing Springs, N. C.<br>Linden, N. J.<br>Toledo, Ohio<br>Galveston, Tex.<br>Albany, Ore.<br>Columbus, Ohio<br>Coos Bay, Ore.<br>Cressett, Ark.<br>Tulsa, Okla.<br>Tulsa, Okla.<br>Vicksburg, Miss.<br>Louisiana, Mo.<br>Wilmington, N. C.<br>Adelphi, Ohio<br>Chocoma, Pa.<br>Tex.<br>Eugene, Ore.<br>Springfield, Mass. | 140.7 (310)<br>45.4 (102)<br>36.3 (80)<br>106.7 (235)<br>36.3 (80)<br>59 (130)<br>102.1 (225)<br>36.3 (80)<br>29.5 (65)<br>109 (240)<br>681 (1500)<br>53.1 (117)<br>53.1 (117)<br>29.5 (65)<br>222.5 (490)<br>136.2 (300)<br>90.8 (200)<br>68.1 (150)<br>118 (260)<br>45.4 (100)<br>54.5 (120)<br>54.5 (120)<br>45.4 (100)<br>72.6 (160)<br>54.5 (130)<br>45.4 (100)<br>20.4 (45)<br>77.2 (170)<br>46.4 (100)<br>46.4 (100)<br>88.5 (195)<br>45.4 (100)<br>133.0 (295) | 1974                               |                                              |

Table A-1. (Continued)

| Chemical     | Use:                                                                                                                                                                                                                                                                                                                                                                | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                | Location(s)                                                                                                                            | 1975 capacity<br>MM kg (MM lb)                                                                     | Total '75<br>production<br>MM kg (MM lb)<br>for year of estimate |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| Formic acid  | Dyeing & finishing of textiles & paper; leather treatment; chemical salts (formates, oxalic acid, organic esters); manufacture of fumigants, insecticides, refrigerants; solvents for perfumes, lacquers; electroplating; medicine; brewing (antiseptic); silvering glass; cellulose formate; natural latex; copolymers; resins; plasticizers; animal feed additive | Celanese Corp. - Celanese Chem. Co., div.<br>Middleboro Indust., Inc.<br>Sonoco Products Co.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                                                                                                                                                                                                                                                   | Farms, Tex.<br>Middleboro, Mass.<br>Hartsville, S. C.<br>Brownsville, Tex.                                                             | 4.5 (10)<br>3.2 (7)<br>.5 (1)<br>22.7 (50)<br>Total =<br>30.9 (68)                                 | -                                                                |
| Pumaric acid | Modifier for polyester, alkyl, & phenolic resins; paper-size resins; plasticizers; rosin esters & adducts; upgrading natural drying oils (especially tall oil) to improve drying characteristics; in foods, core place, titration, plastic stabilizer, emulsifier, flavoring agent (FDA approved); mordant; organic synthesis                                       | Allied Chem. Corp. - Specialty Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.<br>Occidental Petroleum Corp. - Hooker Chem. Corp., subsid.<br>Chems. & Plastics Hooker Chem. Corp., subsid.<br>Tico Chem. Co., subsid.<br>Petro-Tex Chem. Corp. - Petro-Tex Chem. Co., Subsid.<br>Pfizer Inc. - Chems. Div.<br>Tenneco Inc. - Tenneco Chems., Inc. - Organics & Polymers Div.<br>U.S. Steel Corp. - USS Chems., div. | Meunsville, W. Va.<br>St. Louis, Mo.<br>Arecibo, P. R.<br>Houston, Tex.<br>Terre Haute, Ind.<br>Garfield, N. J.<br>Neville Island, Pa. | 6.8 (15)<br>13.6 (30)<br>-<br>3.6 (8)<br>11.3 (25)<br>4.5 (10)<br>4.5 (10)<br>Total =<br>44.5 (98) | 19.1 (42)<br>-1974                                               |

Table A-1. (Continued)

| Chemical                             | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1975<br>Capacity <sup>2</sup><br>MM KG (MM lb.) | Total <sup>4,5</sup><br>Production<br>MM KG (MM lb.)<br>for year of estimate |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------------------------------|
| Glycer-<br>aldehyde<br>(synthetic)   | Biochemical research;<br>intermediate; nutrition;<br>preparation of poly-<br>esters, adhesives, cellu-<br>lose, modifiers; leather<br>tanning                                                                                                                                                                                                                                                                                                                                                        | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | -                                               | -                                                                            |
| Glycerol<br>(natural<br>& synthetic) | Alkyd resins; cello-<br>phane; explosives;<br>ester gums; pharmaceu-<br>ticals; perfumery;<br>plasticizer for<br>regenerated cellulose;<br>cosmetics; foodstuffs;<br>conditioning tobacco;<br>liquors; solvent;<br>printer's ink rolls;<br>polyurethane poly-<br>ols; emulsifying<br>agent; rubber stamp<br>& copying inks; binder<br>for cements & mixes;<br>paper coatings &<br>finishes; special<br>soaps; lubricant &<br>softener; bacteriosta-<br>tic; penetrant; hydraulic<br>fluid; humectant | Natural:<br>Acme-Hardesty Co., Inc.<br>Alta Mfg. Co.<br>Ashland Oil, Inc. -<br>Ashland Chem. Co., div.,<br>Chem. Products Div.<br>Chicago Sanitary Pro-<br>ducts Co.<br>Colgate-Palmolive Co.<br><br>Darling & Co.<br>Dow Chem. Co.<br>Emery Indust., Inc. -<br>Western Operations<br><br>The Greyhound Corp. -<br>Armour & Co., subsid.<br>Armour-Dial, Inc., div.<br>The Andrew Jergens Co.<br>H. Kohnstamm & Co., Inc.<br>Kraftco Corp. -<br>Hucke Sheffield Chem.<br>Lever Brothers Co.<br><br>Millmaster Onyx Corp. -<br>A. Gross & Co., div.<br>Murro Chem. Co.<br>Pacific Soap Co.<br>Pioneer Soap Co., Inc. | Jenkintown, Pa.<br>Aurora, Ill.<br>Hammond, Ind.<br>Morton, Ill.<br>Chicago, Ill.<br>Berkeley, Calif.<br>Jeffersonville, Ind.<br>Jersey City, N. J.<br>Kansas City, Kans.<br>Chicago, Ill.<br>Anchorage, Alas.<br>Cincinnati, Ohio<br>Santa Fe Springs,<br>Calif.<br>Montgomery, Ill.<br><br>Cincinnati, Ohio<br>Clearing, Ill.<br>Memphis, Tenn.<br>Baltimore, Md.<br>Edgewater, N. J.<br>Hammond, Ind.<br>Los Angeles, Calif.<br>St. Louis, Mo.<br>Newark, N. J.<br>Portsmouth, Va.<br>Vernon, Calif.<br>San Francisco,<br>Calif. | 159.1 (348.2) -1969                             |                                                                              |

Table A-1. (Continued)

| Chemical                                             | Manufacturer                                            | Location(s)                                                                                                                                                                                             | 1975 capacity <sup>2</sup><br>MM kg (MM lb)         | Total <sup>1,2,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------|
| Glycerol<br>(cont'd)                                 | The Procter & Gamble Co.                                | Baltimore, Md.<br>Chicago, Ill.<br>Dallas, Tex.<br>Ivory, N. Y.<br>Kansas City, Mo.<br>Long Beach, Calif.<br>Port Ivory, N. Y.<br>Quincy, Mass.<br>Sacramento, Calif.<br>St. Louis, Mo.<br>Dayton, Ohio | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | (See previous page)                                                           |
|                                                      | The Hewitt Soap Co.,<br>Inc., subsid.                   | Bristol, Pa.                                                                                                                                                                                            | -                                                   | -                                                                             |
|                                                      | Purex Corp., Ltd.                                       | Omaha, Neb.<br>Philadelphia, Pa.                                                                                                                                                                        | -<br>-                                              | -<br>-                                                                        |
|                                                      | PVO Internat'l. Inc.                                    | Boston, N. Y.                                                                                                                                                                                           | -                                                   | -                                                                             |
|                                                      | Safeway Stores, Inc. -<br>Newport Products Co.,<br>div. | Oakland, Calif.                                                                                                                                                                                         | -                                                   | -                                                                             |
|                                                      | Stepan Chem. Co. -<br>Surfactant Dept.                  | Anaheim, Calif.<br>Elwood, Ill.                                                                                                                                                                         | -<br>-                                              | -<br>-                                                                        |
|                                                      | Union Carbide Corp. -<br>Chem. Products Div.            | Fieldston, N. J.<br>Dover, Ohio                                                                                                                                                                         | -<br>-                                              | -<br>-                                                                        |
|                                                      | Weburn Chem. Corp.                                      | Kearny, N. J.                                                                                                                                                                                           | -                                                   | -                                                                             |
|                                                      | Synthetic:<br>Dow Chem. U.S.A.                          | Fresno, Tex.                                                                                                                                                                                            | 50 (110)                                            | -                                                                             |
|                                                      | PMC Corp. - Chem.<br>Group - Indust. Chem.<br>Div.      | Bayport, Tex.                                                                                                                                                                                           | 13.2 (40)                                           | -                                                                             |
|                                                      | Shell Chem. Co. -<br>Base Chem.                         | Deer Park, Tex.<br>Norco, La.                                                                                                                                                                           | 44.5 (120)<br>22.7 (50)                             | -                                                                             |
|                                                      | ICI U.S. Inc. -<br>Specialty Chems. Div.                | New Castle, Del.                                                                                                                                                                                        | 195.3 (320)                                         | -                                                                             |
|                                                      | Olin Corp. - Designed<br>Products Div.                  | Brandenburg, Ky.                                                                                                                                                                                        | -                                                   | -                                                                             |
|                                                      | Petron Corp.                                            | Lyons, Ill.                                                                                                                                                                                             | -                                                   | -                                                                             |
|                                                      | Union Carbide Corp. -<br>Chems. & Plastics Div.         | Institute & South<br>Charleston, W. Va.                                                                                                                                                                 | -                                                   | -                                                                             |
|                                                      | Witco Chem. Corp. -<br>Organics Div.                    | Clearing, Ill.                                                                                                                                                                                          | -                                                   | -                                                                             |
| Glycerol<br>tri(poly-<br>oxypropy-<br>lene)<br>ether |                                                         |                                                                                                                                                                                                         |                                                     |                                                                               |



Table A-1. (Continued)

| Chemical  | Use(s) <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                     | Location(s) <sup>2,3</sup>                                                                        | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Glycine   | Organic synthesis;<br>medicine; biochemical<br>research; buffering<br>agent; chicken feed<br>additive; reduces<br>bitter taste of<br>saccharin                                                                                                                                                                                                                                                                                                                             | Chattam Drug & Chem.<br>Co. - Chattam Chem.<br>Div.                                                                                                                                                                                | Chattanooga, Tenn.                                                                                | -                                              | -                                                                           |
| Glyoxal   | Mfg. of textile resins<br>for permanent press<br>process; dimensional<br>stabilization of rayon<br>textiles; fibers; insolu-<br>bilizing agents; com-<br>pounds containing poly-<br>hydroxyl groups (poly-<br>vinyl alcohol, starch,<br>& cellulosic materials);<br>insolubilizing of pro-<br>teins (casein, gelatin<br>& animal glue); embalm-<br>ing fluids; leather<br>tanning; paper coatings<br>with hydroxyethylcellu-<br>lose; reducing agent in<br>dyeing textiles | American Cyanamid Co. -<br>Organic Chems. Div. -<br>(Captive Use)<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Witco Chem. Corp. -<br>Organics Div.                                                                       | Charlotte, N. C.<br>Taft, La.<br>Cleveland, Ill.                                                  | -<br>-<br>-                                    | -                                                                           |
| Guanidine | Organic synthesis                                                                                                                                                                                                                                                                                                                                                                                                                                                          | -                                                                                                                                                                                                                                  | -                                                                                                 | -                                              | -                                                                           |
| Heptene   | Organic synthesis; plant<br>growth retardant; lubri-<br>cant additive; catalyst<br>surfactants                                                                                                                                                                                                                                                                                                                                                                             | American Petrofina Inc.<br>Coastal Oil & Chem. Co.,<br>subsidi.<br>Getty Oil Co.<br>The Humphrey Chem. Co.<br>Phillips Petroleum Co. -<br>Petrochem. & Supply Div.<br>Standard Oil Co. (Ind.) -<br>Amoco Chems. Corp.,<br>subsidi. | Big Springs, Tex.<br>Delaware City, Del.<br>North Haven, Conn.<br>Phillips, Tex.<br>Yorktown, Va. | -<br>-<br>-<br>-<br>-                          | 204 (450) -1967                                                             |

Table A-1. (Continued)

| Chemical                                  | Use(s)                                                                                                                                                                                                                                                                                                                                                                                    | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                           | Location(s)                                                                                                                                                   | 1975 capacity<br>MM kg (MM lb)                                                                   | Totals<br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Hexa-<br>deyl<br>ethane                   | Organic synthesis; re-<br>tarding agent in for-<br>mulation; camphor sub-<br>stitute in nitrocellu-<br>lose; rubber accelera-<br>tor; pyrotechnics &<br>smoke devices; solvent;<br>explosives; medicine                                                                                                                                                                                   | Hummel Chem. Co., Inc.                                                                                                                                                                                                                                                                                                                                                                                                                                    | South Plainfield,<br>N. J.                                                                                                                                    | -                                                                                                | -                                                             |
| Hexa-<br>deyl<br>alcohol                  | Perfumery; emulsifier;<br>emollient; foam stabiliz-<br>er in detergent; face<br>creams; lotions, lip-<br>sticks; toilet prepara-<br>tions; chemical inter-<br>mediates; cosmetics;<br>candles; candles; come-<br>tics; base for making<br>sulfonated fatty alco-<br>hols; to retard evapora-<br>tion of water, when<br>spread as a film on<br>reservoirs, or sprayed<br>on growing plants | Ashland Oil, Inc. -<br>Ashland Chem. Co.,<br>Div. - Chem. Products<br>Div.<br>Continental Oil Co. -<br>Conoco Chems.<br>Givaudan Corp. -<br>Chems. Div.<br>The Procter & Gamble<br>Co.<br>Robinson-Wagner Co.,<br>Inc.                                                                                                                                                                                                                                    | Mapleton, Ill.<br>Westlake, La.<br>Clifton, N. J.<br>Ivydale, Ohio<br>Sacramento, Calif.<br>Maryland, N. Y.                                                   | -<br>-<br>-<br>-<br>-                                                                            | 2.72 (6.0) -1972                                              |
| Hexa-<br>methyl-<br>ene<br>Silyl          | Solvent; resin inter-<br>mediate; coupling<br>agent                                                                                                                                                                                                                                                                                                                                       | Guardian Chem. Corp. -<br>Eastern Chem. Div.                                                                                                                                                                                                                                                                                                                                                                                                              | Hempstead, N. Y.                                                                                                                                              | -                                                                                                | -                                                             |
| Hexa-<br>methyl-<br>ene<br>tetra-<br>mine | Catalyst in phenol-<br>formaldehyde & resorcinol-<br>formaldehyde resins; in-<br>redient in rubber-to-<br>textile adhesives; pro-<br>tein modifier; organic<br>synthesis; pharmaceuticals;<br>ingredient of high<br>explosive cyclonite<br>(q.v.); fuel tablets                                                                                                                           | Borden Inc. - Borden<br>Chem. Div. - Adhesives<br>& Chems. Div. - East<br>W. R. Grace & Co. -<br>Indust. Chems. Group -<br>Dewey & Almy Chem. Div.<br>Occidental Petroleum<br>Corp. - Hooker Chem.<br>Corp., subd. - Hooker<br>Chems. & Plastics Corp. -<br>subd. - Durez Div.<br>Plastics Engineering Co.<br>Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>Polymers Div.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Wright Chem. Corp. | Demopolis, Ala.<br>Fayetteville, N. C.<br>Nashua, N. H.<br>North Tonawanda,<br>N. Y.<br>Sheboygan, Wisc.<br>Ponds, N. J.<br>Round Brook, N. J.<br>Acme, N. C. | 5.4 (12)<br>10.0 (24)<br>-<br>12.7 (28)<br>3.6<br>10 (22)<br>4.5 (10)<br>14.1 (31)<br>61.1 (135) | 45.7 (100.7) -1973                                            |

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Table A-1. (Continued)

| Chemical                          | Usage                                                                                                                                                                                                                                       | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Location(s)                                                                                                                                                                                                                        | 1975<br>capacity,<br>MM kg (MM lb)                                                                                                                             | Total<br>production<br>MM kg (MM lb)<br>for year of estimate |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Hydroxy-<br>quinone<br>cyanide    | Manufacture of acrylo-<br>nitrile, acrylates,<br>adiponitrile, cyanide<br>salts, dyes; fumigant<br>for orchards & tree<br>crops; chelates                                                                                                   | American Cyanamid<br>Co. - Indust. Chems. &<br>Plastics Div.<br>Dow Chem. U.S.A.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Elastomer Chems. Dept.<br>Indust. Chems. Dept.<br>Plastics Dept.<br>Hercules Inc. - Coat-<br>ings & Specialty Products<br>Dept.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.<br>Rohm & Haas Co. - Resin<br>& Haas Texas Inc.,<br>subsidi.<br>The Standard Oil Co.<br>(Ohio) - Vistron Corp.,<br>subsidi. - Chems. Dept. | New Orleans, La.<br><br>Freeport, Tex.<br>Beaumont, Tex.<br>Lafayette, La.<br><br>Memphis, Tenn.<br>Victoria, Tex.<br>Glens Falls, N. Y.<br><br>Chocolate Bayou, Tex.<br>Texas City, Tex.<br><br>Deer Park, Tex.<br><br>Lima, Ohio | 12.2 (27)<br><br>2.3 (5)<br>13.6 (30)<br>9.1 (20)<br><br>57.6 (127)<br>18.2 (40)<br>1.1 (2.4)<br><br>25.4 (56)<br>34.1 (75)<br><br>81.7 (180)<br><br>13.6 (30) | 138.1 (304.3) - 1973                                         |
| Hydro-<br>quinone                 | Photographic deve-<br>loper (except color<br>film); dye intermediate;<br>medicine; antioxidant;<br>inhibitor; stabilizer<br>in paints & varnishes,<br>motor fuels & oils;<br>antioxidant for fats<br>& oils; inhibitor of<br>polymerization | Carus Corp. - Carus<br>Chem. Co., div.<br>Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsidi. - Tenn.<br>Eastman Co., div.<br>The Goodyear Tire &<br>Rubber Co. - Chem. Div.                                                                                                                                                                                                                                                                                 | La Salle, Ill.<br>Kingsport, Tenn.<br><br>Bayport, Tex.                                                                                                                                                                            | 3.5 (7.7)<br>7.3 (16.0)<br><br>2.7 (6.0)                                                                                                                       | Total =<br>269 (592.4)                                       |
| m-<br>hydroxy-<br>benzoic<br>acid | Intermediate for plas-<br>tickers; resins; light<br>stabilizers; petroleum<br>additives; pharmaceuti-<br>cals; intermediates;<br>synthetic drugs                                                                                            | Mallinckrodt, Inc. -<br>Machine Div.<br>Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>& Polymers Div.                                                                                                                                                                                                                                                                                                                                                              | Lodi, N. J.<br>Garfield, N. J.                                                                                                                                                                                                     | Total =<br>13.5 (29.7)                                                                                                                                         | -                                                            |

Table A-1. (Continued)

| Chemical          | Use(s)                                                                                                                                                                                             | Manufacturer(s)                                                                                                                                                                                                                                                            | Location(s)                                                                                                | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Isobutyl alcohol  | Photographic chemicals;<br>organic synthesis; pharmaceutical products; medicines; solvents; determination of fat in milk; microscopes; flavoring                                                   | Publicker Indust. Inc.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                   | Gretna, La.<br>Philadelphia, Pa.<br>Institute & South<br>Charleston, W. Va.                                | -                                           | -                                                                           |
| Isobutyl chloride | Mixtures, usually also containing water, amyl, ethyl, and solvent<br>intercellulose, varnishes, lacquers, resins; rotogravure inks; soil fumigation; organic compounds                             | -                                                                                                                                                                                                                                                                          | -                                                                                                          | -                                           | -                                                                           |
| Isocyanide        | Organic synthesis;<br>dental & surgical<br>anesthetic; high octane fuel manufacture                                                                                                                | Phillips Petroleum Co. -<br>Petrochem & Supply Div.                                                                                                                                                                                                                        | Phillips, Tex.                                                                                             | -                                           | -                                                                           |
| Isobutanol        | Organic synthesis; latent solvent in paints & varnishes; intermediate for plastic coating resins; substitute for butyl alcohol, paint removers; fluorometric determinations; liquid chromatography | Dow Badische Co.<br>W. R. Grace & Co. -<br>Hatch Group - Hatch<br>Chem. Div.<br>Oxochem Enterprise                                                                                                                                                                         | Freeport, Tex.<br>Pords, N. J.<br>Peneelas, P. R.                                                          | -                                           | -                                                                           |
| Isobutyl acetate  | Solvent for nitrocellulose in thinners, sealants, & topcoat lacquers; perfumery; flavoring agent                                                                                                   | Eastman Kodak Co. -<br>Eastman Chem. Products Inc., subd. - Tenn.<br>Eastman Co., div.<br>Fritzsche Dodge &<br>Olcott Inc.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                               | Kingsport, Tenn.<br>East Hanover, N. J.<br>Institute & South<br>Charleston, W. Va.<br>Texas City, Tex.     | -                                           | 5.3 (11.75) -1972                                                           |
| Isobutylaldehyde  | Intermediate for other antioxidants & accelerators, for refrigerant glycol; organic synthesis                                                                                                      | Celanese Corp. -<br>Celanese Chem. Co., div.<br>Dow Badische Co.<br>Eastman Kodak Co. -<br>Eastman Chem. Products Inc., subd. - Texas<br>Eastman Co., div.<br>Oxochem Enterprise<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>Union Carbide Carbons<br>Inc., subd. | Bisby, Tex.<br>Freeport, Tex.<br>Lancaster, Tex.<br>Peneelas, P. R.<br>Texas City, Tex.<br>Peneelas, P. R. | -                                           | -                                                                           |

Table A-1. (Continued)

| Chemical                  | Usage <sup>1</sup>                                                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                   | Location(s) <sup>3</sup>                                                                                  | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Iso-<br>butyric<br>acid   | Manufacture of esters<br>for solvents, flavors,<br>& perfume bases; dye-<br>infesting agent;<br>deliming aides;<br>varnish; tanning<br>agent                                                                                 | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. - Tenn.<br>Eastman Co., div.                                                                                     | Kingsport, Tenn.                                                                                          | -                                              | -                                                                           |
| Iso-<br>decanoic<br>acid  | Intermediate for metal<br>salts, ester type<br>lubricants, plasticizers                                                                                                                                                      | Union Carbide Corp. -<br>Chems. & Plastics<br>Div.                                                                                                                               | Texas City, Tex.                                                                                          | -                                              | -                                                                           |
| Iso-<br>decanol           | Antifoaming agent in<br>textile processing                                                                                                                                                                                   | Exxon Corp. -<br>Exxon Chem. Co., div. -<br>Exxon Chem. Co. U.S.A.<br>Getty Oil Co.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>U.S. Steel Corp. - USS<br>Chems., div. | Baton Rouge, La.<br><br>Delaware City, Del.<br>Institute & South<br>Charleston, W. Va.<br>Haverhill, Ohio | -<br>-<br>-<br>-<br>-                          | 81.7 (180)<br>-1974                                                         |
| Iso-<br>decyl<br>chloride | Solvent for oils, fats,<br>greases, resins, gums,<br>extractants, cleaning<br>compounds; intermediate<br>for insecticides, phar-<br>macuticals, plasticizers,<br>polysulfide rubbers,<br>resins, & cationic sur-<br>factants | -                                                                                                                                                                                | -                                                                                                         | -                                              | -                                                                           |
| Iso-<br>octyl<br>alcohol  | Ingredient of plastici-<br>zers; intermediate for<br>non-ionic detergent &<br>surfactants; synthetic<br>drying oils, cutting &                                                                                               | Exxon Corp. - Exxon<br>Chem. Co., div. - Exxon<br>Chem. Co. U.S.A.<br>Getty Oil Co.                                                                                              | Baton Rouge, La.<br><br>Delaware City, Del.                                                               | -<br>-                                         | 55.4 (122)<br>-1967                                                         |

Table A-1. (Continued)

| Chemical                     | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                            | Location(s) <sup>2,3</sup>                                                                                                              | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                 | Total <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>For year of estimate |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Isocetyl alcohol<br>(cont'd) | (See previous page)<br>Lubricating oils, hydraulic fluids, greases, solvents, emulsifiers, antiflaming agents, intermediate for insecticides, pharmaceuticals, plasticizers, polysulfone rubbers, resins, & cationic surfactants                                                                                                                    | U.S. Steel Corp. -<br>USS Chem., div.                                                                                                                                                                                                                                                                     | Delaware City,<br>Tex.                                                                                                                  | -                                                                                                           | -                                                                           |
| Isophorone                   | In solvent mixtures for finishes; for polyvinyl & nitrocellulose resins; pesticides; stoving lacquers                                                                                                                                                                                                                                               | Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                                                                            | Institute & South<br>Charleston, W. Va.                                                                                                 | -                                                                                                           | -                                                                           |
| Isophthalic acid             | Polyester, alkyl, polyurethanes, & other high polymers; plasticizers                                                                                                                                                                                                                                                                                | Standard Oil Co. (Ind.) -<br>Amoco Chem. Corp.,<br>subsidi.                                                                                                                                                                                                                                               | Peoria, Ill.                                                                                                                            | 40.9 (90)<br>Total =<br>40.9 (90)                                                                           | 53.6 (118) -1974                                                            |
| Isoprene                     | Monomer for manufacture of polyisoprene; chemical intermediate                                                                                                                                                                                                                                                                                      | Carlin Isoprene Corp.<br>Exxon Corp. - Exxon<br>Chem. Co., div. - Exxon<br>Chem. Co. U.S.A.<br>The Goodyear Tire &<br>Rubber Co. - Chem. Div.<br>Neches Butane Products<br>Co.<br>Shell Chem. Co. - Base<br>Chem.                                                                                         | Pease, P. R.<br>Baton Rouge, La.<br>Resident, Tex.<br>Port Neches, Tex.<br>Deer Park, Tex.<br>Wood River, Ill.                          | 30 (66)<br>4.5 (10)<br>76.3 (168)<br>45.4 (100)<br>55.8 (123)<br>Total =<br>182 (401)                       | 151.8 (334.3) -1971                                                         |
| Isopropanol                  | Manufacture of acetone & its derivatives; manufacture of glycerol & isopropyl alcohol; solvent for essential oils; other oils, alkaloids, gums, resins, etc.; latent solvent for cellulose derivatives; coatings solvent; deicing agent for liquid fuels; pharmaceuticals; perfumes; lacquers; extraction processes; denaturing agent; preservative | Atlantic Richfield Co. -<br>ARCO Chem. Co., div.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc.,<br>subsidi. - Texas Eastman<br>Co., div.<br>Exxon Corp. - Exxon Chem.<br>Co., div. - Exxon Chem.<br>Co. U.S.A.<br>Shell Chem. Co. -<br>Base Chem.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. | Chancellorview, Tex.<br>Longview, Tex.<br>Baton Rouge, La.<br>Deer Park, Tex.<br>Dominique, Calif.<br>Texas City, Tex.<br>Whiting, Ind. | 15.9 (35)<br>-<br>274.2 (614)<br>276.9 (610)<br>94 (207)<br>89 (197)<br>89 (197)<br>Total =<br>835.8 (1841) | -                                                                           |

Table A-1. (Continued)

| Chemical                   | Use(s)                                                                                                                                                                                                                                      | Manufacturer(s)                                                                                                                            | Location(s)                                                            | 1975 capacity,<br>MM KG (MM lb)            | Total's<br>production<br>MM KG (MM lb)<br>for year of estimate |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------|----------------------------------------------------------------|
| Iso-<br>propyl<br>acetate  | Solvent for nitrocellulose, resin gums, etc.; paints, lacquers, & printing inks, organic synthesis                                                                                                                                          | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn. Eastman Co., div. Union Carbide Corp. - Chems. & Plastics Div.           | Kingsport, Tenn. Institute & South Charleston, W. Va. Texas City, Tex. | 4.5 (10)<br>13.6 (30)<br>Total = 18.1 (40) | -                                                              |
| Iso-<br>propyl-<br>amine   | Solvent; intermediate in synthesis of rubber accelerators, pharmaceuticals, dyes, insecticides; bactericides, textile specialties, & surface-active agents; denaturing agent; solubilizer for 2,4-D acid                                    | Air Products & Chems., Inc. Fenwal Corp. - Chem. Div. Union Carbide Corp. - Chems. & Plastics Div. Va. Chems. Inc. - Indust. Chems. Dept.  | Pensacola, Fla. Wyandotte, Mich. Taft, La. Portsmouth, Va.             | -<br>-<br>-<br>-                           | -                                                              |
| Iso-<br>propyl<br>chloride | Solvent; intermediate; isopropylamine                                                                                                                                                                                                       | Occidental Petroleum Corp. - Hooker Chem. Corp., subsid. - Hooker Chems. & Plastics Corp., subsid. Electrochemical & Specialty Chems. Div. | Niagara Falls, N. Y.                                                   | -                                          | -                                                              |
| Isopropyl-<br>phenyl       | Intermediate for synthetic resins, plasticizers, surface active agents, perfumes                                                                                                                                                            | Ethyl Corp. - Productol Chem. Co.                                                                                                          | Orangeburg, S. C. Santa Fe Springs, Calif.                             | -<br>-                                     | -                                                              |
| Ketene                     | Acetylating agent, generally reacting with compounds having an active hydrogen atom; reacts with ammonia to give acetamide; starting point for making various commercially important products, especially acetic anhydride & acetate esters | Monsanto Co. - Monsanto Indust. Chems. Co.                                                                                                 | Muscatine, Iowa                                                        | -                                          | -                                                              |

Table A-1. (Continued)

| Chemical         | Use <sup>1</sup>                                                                                                                                                                        | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                  | Location(s) <sup>2,3</sup>                                                                                                                                               | 1975 capacity <sup>2</sup><br>MM KS (MM lb)                                                        | Total <sup>1,2,3</sup><br>production<br>MM KS (MM lb)<br>for year of estimate |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Maleic acid      | Organic synthesis (malic, succinic, aspartic, tartaric, propionic, lactic, malonic, acrylic, hydroxylic acids); dyeing & finishing of cotton, wool & silk; preservative for oils & fats | Pfanstiehl Labs., Inc.                                                                                                                                                                                                                                                                                                          | Waukegan, Ill.                                                                                                                                                           | -                                                                                                  | -                                                                             |
| Maleic anhydride | Polyester resins; alkyl coating resins; fumigant; insect repellent; preservative for oils & fats; paper; permanent-press resins (textiles)                                              | Allied Chem. Corp. - Specialty Chem. Div.<br>Koppers Co., Inc. - Organic Materials Div.<br>Monsanto Co. - Monsanto Indust. Chem. Co.<br>Petro-Tex Chem. Corp. - Petro-Tex Chem. Co., subsidi.<br>Reichhold Chem., Inc.<br>Tenneco Inc. - Tenneco Chems., Inc. - Organics & Polymers Div.<br>U.S. Steel Corp. - USC Chems., div. | Moundsville, W. Va.<br>Bridgeville, Pa.<br>St. Louis, Mo.<br>Houston, Tex.<br>Elizabeth, N. J.<br>Morris, Ill.<br>Fords, N. Y.<br>Neville Island,<br>Neville Island, Pa. | 9.1 (20)<br>15.4 (34)<br>47.7 (105)<br>22.7 (50)<br>13.6 (30)<br>27.2 (60)<br>10 (22)<br>18.2 (40) | 128.5 (283) -1974                                                             |
| Maleic acid      | Medicine; manufacture of various esters & salts; insect repellent; food antioxidant; flavoring                                                                                          | Allied Chem. Corp. - Specialty Chem. Div.<br>Morse Labs. Inc.                                                                                                                                                                                                                                                                   | Moundsville, W. Va.<br>Santa Barbara, Calif.                                                                                                                             | -                                                                                                  | -                                                                             |
| Maleic oxide     | Solvent for cellulose esters & ethers, oils, gums, resins, lacquers, roll-coating inks, stains, ore flotation; paint & varnish-removers; insect repellent                               | Shell Chem. Co. - Base Chem.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                                                                                                                                                                                                                    | Deer Park, Tex.<br>Dominguez, Calif.<br>Institute & South Charleston, W. Va.                                                                                             | -<br>-<br>-                                                                                        | -                                                                             |



Table A-1. (Continued)

| Chemical                     | Usage 1                                                                                                                                                                                                                                                                                                                                                                                                              | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                   | Location(s) <sup>2,3</sup>                                                                                                                   | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                                | Total <sup>4,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Meth-<br>acrylic<br>acid     | Monomer for large-volume<br>uses: acrylic polymers;<br>acrylic nitriles; many<br>of the polymers are<br>based on esters of the<br>acid, as the methyl,<br>butyl, or isobutyl,<br>esters (see acrylic<br>resin)                                                                                                                                                                                                       | E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Biochems. Dept.<br>Rohm & Haas Co.                                                                                                                                                                                                                | Beile, W. Va.<br>Bristol, Pa.                                                                                                                | -<br>-                                                                                                                     | 30.9 (68) -1968                                                             |
| Meth-<br>acrylic-<br>nitrile | Vinyl nitrile monomer;<br>copolymer with styrene,<br>butadiene, etc.; elastom-<br>ers, coatings,<br>plastics                                                                                                                                                                                                                                                                                                         | The Standard Oil<br>Co. (Ohio); Vistron<br>Corp., subsid. -<br>Chems. Dept.                                                                                                                                                                                                                      | Lima, Ohio                                                                                                                                   | -                                                                                                                          | -                                                                           |
| Meth-<br>allyl<br>alcohol    | Intermediate                                                                                                                                                                                                                                                                                                                                                                                                         | -                                                                                                                                                                                                                                                                                                | -                                                                                                                                            | -                                                                                                                          | -                                                                           |
| Meth-<br>allyl<br>chloride   | Intermediate for pri-<br>duction of insecticides,<br>plastics, pharmaceuticals,<br>other organic chemicals;<br>fumigant for grains,<br>tobacco, & soil                                                                                                                                                                                                                                                               | PMC Corp. - Chem. Group<br>Indust. Chem. Div.<br>Stauffer Chem. Co. -<br>Specialty Chem. Div.                                                                                                                                                                                                    | Baltimore, Md.<br>Edison, N. J.                                                                                                              | -<br>-                                                                                                                     | -                                                                           |
| Methanol                     | Manufacture of formalde-<br>hyde & dimethyl terephtha-<br>late; chemical synthesis<br>of ethyl amines, methyl<br>acrylate, methyl meth-<br>acrylate, etc.; avia-<br>tion fuel (for jet en-<br>gines); automotive<br>antifreeze; solvent for<br>nitrocellulose, ethylcel-<br>lulose, polyvinyl butyral,<br>shellac, rosin, manila<br>resin, dyes; denaturant<br>for ethyl alcohol; de-<br>hydrator for natural<br>gas | Alr Products & Chems.,<br>Inc.<br>Borden Inc. - Borden<br>Chem. Div. - Petrochems.<br>Celanese Corp. -<br>Celanese Chem. Co., div.<br>Commercial Solvents<br>Corp.<br>E. I. du Pont de Ne-<br>mours & Co., Inc.<br>Elastomer Chems. Dept.<br>Plastics Dept.<br>Ga.-Pacific Corp. -<br>Chem. Div. | Pensacola, Fla.<br>Geismar, La.<br>Bishop, Tex.<br>Clear Lake, Tex.<br>Sterlington, La.<br>Beaumont, Tex.<br>Orange, Tex.<br>Plaquemine, La. | 189.8 (330)<br>479.4 (1,056)<br>179.8 (396)<br>689.2 (1,518)<br>189.8 (330)<br>500.3 (1,120)<br>344.6 (759)<br>299.6 (660) | 3,082 (6,790) -1974                                                         |

Table A-1. (Continued)

| Chemical          | Use(s)<br>(See previous page)                                                                                                                                                                                                                                                                                  | Manufacturer(s)                                                                                                                                                                                                                                                                                                                           | Location(s)                                                                                                                                                                                                                                | 1975<br>capacity<br>MM kg (MM lb)                                                     | Total<br>production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Methanol          |                                                                                                                                                                                                                                                                                                                | Hercules Inc. -<br>Synthetic Dept.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochem.<br>Co.<br>Rohm & Haas Co. - Rohm<br>& Haas Texas Inc.,<br>subsidiary<br>Tenneco Inc. - Tennessee<br>Chem. Inc. - Organics<br>& Polymers Div.                                                                                                       | Hercules, Calif.<br>Flaquemine, La.<br>Texas City, Tex.<br>Deer Park, Tex.<br>Houston, Tex.                                                                                                                                                | -<br>299.6 (660)<br>299.6 (660)<br>65.9 (1,452)<br>239.7 (528)                        | -<br>-<br>-<br>-<br>-                                                               |
| Methyl<br>acetate | Paint remover com-<br>pounds; lacquer<br>solvent; intermediate                                                                                                                                                                                                                                                 | Borden Inc. - Borden<br>Chem. Div. - Therm-<br>plastic Products<br>Eastman Kodak Co. -<br>Eastman Organic Chem.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochem.<br>Co.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsidi.<br>Tenn. Eastman Co., div.<br>Lonza Inc. | Saintbridge, N. Y.<br>Compton, Calif.<br>Tomball, Ala.<br>Chicago, Ill.<br>Leominster, Mass.<br>Rochester, N. Y.<br>Springfield, Mass.<br>Institute & South<br>Charleston, W. Va.<br>Kingsport, Tenn.<br>Mapleton, Ill.<br>Pensacola, Fla. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>22.7 (50)                           | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>85.1 (187.4) -1973                |
| Methyl-<br>amine  | Intermediate for accel-<br>erators, dyes, pharmaceuti-<br>cals; insecticides; fun-<br>gicides; surface active<br>agents; tanning; dyeing<br>resists; textiles; fuel<br>additives; polymeri-<br>zation inhibitor; com-<br>ponent of paint resins;<br>solvent; photo-<br>graphic developer;<br>rocket propellant | Air Products & Chem.<br>Inc.<br>Commercial Solvents<br>Corp.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Biochem. Dept.<br>GAP Corp. - Chem. Div.<br>Rohm and Haas Co.                                                                                                                                                              | Terre Haute, Ind.<br>Belle, W. Va.<br>La Porte, Tex<br>Calvert City, Mo.<br>Philadelphia, Pa.                                                                                                                                              | 8.2 (18)<br>74.9 (165)<br>11.8 (26)<br>4.5 (10)<br>6.3 (14)<br>Total =<br>128.5 (283) | -<br>-<br>-<br>-<br>-<br>-                                                          |

Table A-1. (Continued)

| Chemical             | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                                           | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                      | 1975<br>capacity <sup>2</sup><br>MM KG (MM lb)                                                                                                             | Total <sup>4,5</sup><br>Production <sup>4</sup><br>MM KG (MM lb)<br>for year of estimate |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| N-methyl-<br>aniline | Organic synthesis;<br>solvent; acid ac-<br>ceptor                                                                                                                                                                                                                                                                                                                                            | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>American Cyanamid Co. -<br>Organic Chems. Div.                                                                                                                                                                                                                                                                                                                                                                                                                                            | Buffalo, N. Y.<br>Round Brook, N. J.                                                                                                                                                                                                                                                            | -<br>-                                                                                                                                                     | -                                                                                        |
| Methyl<br>tutynol    | Stabilizer in chlori-<br>nated solvents; vis-<br>cosity reducer; stab-<br>ilizer; electroplating<br>brightener; inter-<br>mediate                                                                                                                                                                                                                                                            | Air Products & Chems.,<br>Acetylenic Chems.<br>Div.<br>Hoffmann-La Roche Inc.                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Calvert City, Ky.<br>Nutley, N. J.                                                                                                                                                                                                                                                              | -<br>-                                                                                                                                                     | -                                                                                        |
| Methyl<br>chloride   | Catalyst carrier in low-<br>temperature polymeriza-<br>tion (butyl lead, allyl-<br>tetramethyl lead, allyl-<br>cones); refrigerant; medi-<br>cine; fluid for thermo-<br>metric & thermostatic<br>equipment; methylating<br>agent in organic syn-<br>thesis, such as methyl-<br>cellulose; extractant &<br>low-temperature solvent;<br>propellant in high-<br>pressure aerosols;<br>herbicide | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>Continental Oil Co. -<br>Conoco Chems.<br>Diamond Shamrock Corp. -<br>Diamond Shamrock Chem.<br>Co. - Electro Chems. Div.<br>Dow Chem. U.S.A.<br>Dow Corning Corp.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Indust. Chems. Dept.<br>Ethyl Corp.<br>Gen. Electric Co. -<br>Chem. & Metallurgical<br>Div. - Silicone Pro-<br>ducts Dept.<br>Stauffer Chem. Co. -<br>Indust. Chem. Div.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Vulcan Materials Co. -<br>Chems. Div. | Moundsville, W. Va.<br>Westlake, La.<br>Zellie, N. Va.<br>Plaquemine, La.<br>Carnollton, Ky.<br>Midland, Mich.<br>Niagara Falls, N. Y.<br>Baton Rouge, La.<br>Waterford, N. Y.<br>Louisville, Ky.<br>Institute & South<br>Charleston, W. Va.<br>Geismar, La.<br>Newark, N. J.<br>Wichita, Kans. | 11.3 (25)<br>45.4 (100)<br>11.3 (25)<br>68.1 (150)<br>9.1 (20)<br>6.8 (15)<br>36.3 (80)<br>45.4 (100)<br>22.7 (50)<br>6.8 (15)<br>22.7 (50)<br>-<br>-<br>- | 201.8 (444.5) -1973                                                                      |
|                      |                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                 | Total <sup>4</sup><br>286 (630)                                                                                                                            |                                                                                          |

Table A-1. (Continued)

| Chemical           | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                        | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                        | Location(s) <sup>2,3</sup>                                                                                    | 1975 capacity, <sup>2</sup><br>MM KG (MM lb)                                | Total <sup>4,5</sup><br>production<br>MM KG (MM lb)<br>for year of estimate |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Methylcyclohexane  | Solvent for cellulose ethers; organic synthesis                                                                                                                                                                                                                                                                                                           | Phillips Petroleum Co. - Petrochem. & Supply Div.<br>Lonza Inc.                                                                                                                                                                                       | Phillips, Tex.<br>Marietta, Ill.                                                                              | -<br>-                                                                      | -<br>-                                                                      |
| Methylcyclohexanol | Solvent; lacquers; solvent for cellulose esters & ethers for lacquers; antioxidant for lubricants; blending agent for special textile soaps & detergents                                                                                                                                                                                                  | Frank Enterprises                                                                                                                                                                                                                                     | Columbus, Ohio                                                                                                | -                                                                           | -                                                                           |
| Methyldioxolane    | Extraction & solvent for oils, fats, waxes, dyestuffs, & cellulose derivatives                                                                                                                                                                                                                                                                            | -                                                                                                                                                                                                                                                     | -                                                                                                             | -                                                                           | -                                                                           |
| Methylformate      | Organic synthesis; cellulose acetate solvent; military poison gases; fumigant; larvicides                                                                                                                                                                                                                                                                 | Celanese Corp. - Celanese Chem. Co., div.<br>E. I. du Pont de Nemours & Co., Inc. - Biochems. Dept.                                                                                                                                                   | Pampa, Tex.<br>Beale, W. Va.                                                                                  | -<br>-                                                                      | -<br>-                                                                      |
| Methylene chloride | Paint removers; special photographic film; fumigant; solvent degreasing; solvent mixtures for cellulose esters & ethers; textile & leather coatings; refrigeration; local anesthetic; pharmaceutical & food extraction; plastics processing; spotting agent; dewaxing; chemical (organic synthesis); as a propellant for aerosols; blowing agent in foams | Allied Chem. Corp. - Specialty Chems. Div.<br>Diamond Shamrock Corp. - Diamond Shamrock Chem. Co. - Electro Chems. Div.<br>Dow Chem. U.S.A.<br>E. I. du Pont de Nemours & Co., Inc. - Indust. Chems. Dept.<br>Stauffer Chem. Co. - Indust. Chem. Div. | Mountsville, W. Va.<br>Beale, W. Va.<br>Freeport, Tex.<br>Flaquemine, La.<br>Niagara Falls<br>Louisville, Ky. | 22.7 (50)<br>27.2 (60)<br>56.1 (150)<br>40.9 (90)<br>18.2 (40)<br>27.2 (60) | 214 (471.3) -1973                                                           |

Table A-1. (Continued)

| Chemical                          | Usage <sup>1</sup><br>(See previous page)                                                                                                                                                                                                                          | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                         | Location(s) <sup>2,3</sup>                                                                                                                                                      | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                                                                             | Total <sup>2,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Methylene<br>chloride<br>(cont'd) |                                                                                                                                                                                                                                                                    | Vulcan Materials Co. -<br>Chems. Div.                                                                                                                                                                                                                                                                                                                                                                                                                  | Geismar, La.<br>Newark, N. J.<br>Wichita, Kans.                                                                                                                                 | 15.2 (40)<br>13.6 (30)<br>Total =<br>286.1 (520)                                                                           |                                                                                                    |
| Methylene<br>dianiline            | Determination of tungsten & sulfates; polymer & dye intermediate; corrosion inhibitor; epoxy resin hardening agent                                                                                                                                                 | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>Dow Chem. U.S.A.<br>Möbay Chem. Corp. -<br>Indust. Chems. Div.<br>Ruhlen Chem. Inc.                                                                                                                                                                                                                                                                                                                   | Moundsville, W. Va.<br>Midland, Mich.<br>New Martinsville,<br>W. Va.<br>Geismar, La.                                                                                            | -<br>-<br>-<br>-                                                                                                           | -                                                                                                  |
| Methyl<br>ethyl<br>ketone         | Solvent in nitrocellulose coatings & vinyl films; "Glyptal" resins; paint removers; cements & adhesives; organic synthesis; manufacture of smokeless powder; cleaning fluids; printing; catalyst carrier; Note: does not dissolve cellulose acetate and most waxes | Atlantic Richfield Co. - ARCO Chem. Co., div.<br>Celanese Corp. -<br>Celanese Chem. Co., div.<br>Dart Indust., Inc. -<br>Chem. Group - Chem. Specialties Sector -<br>Asteo Chems.<br>Dixie Chem. Co.<br>Eastman Kodak Co. -<br>Eastman Chem. Products, Inc., subd. - Tenn.<br>Eastman Co., div.<br>Exxon Corp. - Exxon Chem. Co., div. -<br>Exxon Chem. Co. U.S.A.<br>Shell Chem. Co. - Base Chems.<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Channelview, Tex.<br>Pampa, Tex.<br>Elyria, Ohio<br>Bayport, Tex.<br>Kingsport, Tex.<br>Bayway, N. J.<br>Deer Park, Tex.<br>Martinez, Calif.<br>Norco, La.<br>Brownsville, Tex. | 29 (64)<br>52.2 (115)<br>-<br>1.4 (3)<br>-<br>90.8 (200)<br>45.4 (100)<br>22.7 (50)<br>27.2 (60)<br>Total =<br>268.8 (592) | 229.6 (505.8) -1974                                                                                |

Table A-1. (Continued)

| Chemical                        | Use(s) <sup>1</sup>                                                                                                                                                                                                                                                                                         | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                          | Location(s) <sup>2,3</sup>                                                                                                   | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                     | Total <sup>3,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Methyl-<br>isobutyl<br>carbinol | Solvent for dyestuffs;<br>cells, gums, resins;<br>waxes, nitrocellulose<br>& ethylcellulose; or-<br>ganic synthesis; froth<br>flotation; brake fluids                                                                                                                                                       | Shell Chem. Co. -<br>Base Chem.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                       | Deer Park, Tex.<br>Dominguez, Calif.<br>Institute & South<br>Charleston, W. Va.                                              | -<br>-<br>-                                                                                     | 15.9 (35) -1973                                                             |
| Methyl-<br>isobutyl<br>ketone   | Solvent for paints, var-<br>nishes, nitrocellulose<br>lacquers; manufacture of<br>methyl amyl alcohol;<br>extraction processes,<br>including extraction of<br>uranium from fission pro-<br>ducts; organic synthesis;<br>denaturant for alcohol                                                              | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsid. - Tenn.<br>Eastman Co., div.<br>Exxon Corp. - Exxon<br>Chem. Co., div. -<br>Exxon Chem. Co. U.S.A.<br>Shell Chem. Co. -<br>Base Chem.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. | Kingsport, Tenn.<br><br>Bayway, N. J.<br><br>Deer Park, Tex.<br>Dominguez, Calif.<br>Institute & South<br>Charleston, W. Va. | 13.6 (30)<br><br>18.2 (40)<br><br>36.3 (80)<br>15.9 (35)<br>29.5 (65)<br>Total =<br>113.5 (250) | 70.3 (154.8)-1973                                                           |
| Methyl-<br>pentynol             | Stabilizer in chlorinated<br>solvents; viscosity re-<br>ducer; electroplating<br>brightening; intermediate<br>in syntheses of hypnotics<br>& isoprenoid chemicals;<br>solvent for polyamide re-<br>sins; acid inhibitor;<br>prevention of hydrogen<br>embrittlement; anesthetic<br>(isopropyl & anesthetic) | Air Products & Chem.<br>Inc. - Acetylenic<br>Chem. Div.<br>Hoffman-La Roche Inc.                                                                                                                                                                        | Calvert City, Ky.<br><br>Nutley, N. J.                                                                                       | -<br>-                                                                                          | -                                                                           |
| Methyl-<br>phenyl-<br>carbinol  | Perfumery; flavoring;<br>dyes; laboratory<br>reagent                                                                                                                                                                                                                                                        | Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                          | Institute & South<br>Charleston, W. Va.                                                                                      | -                                                                                               | -                                                                           |

Table A-1. (Continued)

| Chemical                                 | Use <sup>1</sup>                                                                                                                                                                                                                      | Manufacturer(s) <sup>2,3</sup>                                               | Location(s) <sup>2,3</sup> | 1975<br>Capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>3,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate |
|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| a-Methyl-<br>styrene                     | Polymerization monomer,<br>especially for polyester                                                                                                                                                                                   | Allied Chem. Corp. -<br>Specialty Chems. Div.                                | Frankford, Pa.             | 6.8 (15)                                       | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Clark Oil & Refining<br>Corp. - Clark Chem.<br>Corp., subsid.                | Blue Island, Ill.          | 2.3 (5)                                        | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Dow Chem. U.S.A.<br>Chem. Div.                                               | Midland, Mich.             | 4.5 (10)                                       | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Ga.-Pacific Corp. -<br>Chem. Div.                                            | Pasadena, La.              | 4.5 (10)                                       | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Skelly Oil Co.                                                               | El Dorado, Kans.           | 1 (2)                                          | -                                                                           |
| Morpho-<br>line                          | Rubber accelerator;<br>solvent; organic<br>synthesis; additive to<br>boiler water; waxes<br>& polishes; corro-<br>sion inhibitor; optical<br>brightener for<br>detergents                                                             | Union Carbide Corp. -<br>Chems. & Plastics Div.                              | Bound Brook, N. J.         | 3.6 (8)                                        | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | U.S. Steel Corp. - USS<br>Chems., div.                                       | Haverhill, Ohio            | 6.8 (15)                                       | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Texaco Inc. - Jefferson<br>Chem. Co., Inc., subsid.                          | Conroe, Tex.               | 6.8 (15)                                       | -                                                                           |
|                                          |                                                                                                                                                                                                                                       |                                                                              |                            | Total =<br>29.5 (65)                           | -                                                                           |
|                                          |                                                                                                                                                                                                                                       |                                                                              |                            | Total =<br>6.8 (15)                            | -                                                                           |
| a-naphtha-<br>lene sul-<br>fonic<br>acid | Starting point in the<br>manufacture of alpha-<br>naphthol; alpha-naph-<br>thyl sulfonates; alpha-<br>naphthylamine; alpha-<br>sulfonic acid; solvent<br>(sodium salt) for<br>phenol in the manu-<br>facture of disinfectant<br>soaps | Chattam Drug & Chem. Co.,<br>subsid.                                         | Long Beach, Calif.         | -                                              | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Petrochems. Co., Inc.,<br>subsid.                                            |                            | -                                              | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Diamond Shamrock Corp. -<br>Diamond Shamrock Chem.<br>Co. - Mopco Chem. Div. | Cedartown, Ga.             | -                                              | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Eastern Color & Chem. Co.                                                    | Providence, R. I.          | -                                              | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Emkay Chem. Co.                                                              | Elizabeth, N. J.           | -                                              | -                                                                           |
| a-naphtha-<br>lene sul-<br>fonic<br>acid | Starting point in the<br>manufacture of alpha-<br>naphthol; alpha-naph-<br>thyl sulfonates; alpha-<br>naphthylamine; alpha-<br>sulfonic acid; solvent<br>(sodium salt) for<br>phenol in the manu-<br>facture of disinfectant<br>soaps | Toms River Chem. Corp.                                                       | Toms River, N. J.          | -                                              | -                                                                           |
|                                          |                                                                                                                                                                                                                                       | Mitco Chem. Corp. -<br>Ultra Div.                                            | Clearing, Ill.             | -                                              | -                                                                           |

Table A-1. (Continued).

| Chemical           | Usage                                                                                                                                                                                                      | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                            | Location(s)                                                                                                                                                                               | 1975 capacity, <sup>a</sup><br>MM kg (MM lb)                                                                               | Total <sup>b</sup> production,<br>MM kg (MM lb)<br>for year of estimate |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| $\alpha$ -naphthol | Starting point in the manufacture of beta-naphthol, beta-naphthylsulfonic acid, beta-naphthylamine-sulfonic acid; etc.                                                                                     | American Cyanamid Co. - Fine Chem. Dept.<br>(See also $\alpha$ -naphthylsulfonic acid)                                                                                                                                                                                                                                                                                     | Bound Brook, N. J.                                                                                                                                                                        | -                                                                                                                          | -                                                                       |
| $\alpha$ -naphthol | Dyes; organic synthesis; synthetic perfumes                                                                                                                                                                | Union Carbide Corp. - Chem. & Plastics Div.                                                                                                                                                                                                                                                                                                                                | Institute & South Charleston, W. Va.                                                                                                                                                      | -                                                                                                                          | -                                                                       |
| $\beta$ -naphthol  | Dyes; pigments; antioxidants; insecticides; herbicides; fungicides; pharmaceuticals, perfumes                                                                                                              | American Cyanamid Co. - Organic Chems. Div.                                                                                                                                                                                                                                                                                                                                | Willow Island, W. Va.                                                                                                                                                                     | -                                                                                                                          | 10.8 (23.8) -1955                                                       |
| Neo-pentanoic acid | Intermediate, as a replacement for some natural materials                                                                                                                                                  | Exxon Corp. - Exxon Chem. Co., div.<br>Exxon Chem. Co. U.S.A.                                                                                                                                                                                                                                                                                                              | Baton Rouge, La.                                                                                                                                                                          | -                                                                                                                          | -                                                                       |
| Nitroanisole       | Organic synthesis; manufacture of intermediates for dyes & pharmaceuticals                                                                                                                                 | E. I. du Pont de Nemours & Co., Inc. - Organic Chems. Dept. - Dyes & Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.                                                                                                                                                                                                                                             | Deepwater, N. J.<br>St. Louis, Mo.                                                                                                                                                        | -                                                                                                                          | -                                                                       |
| Nitrobenzene       | Manufacture of aniline; solvent for cellulose ethers; modifying agent; terification of cellulose acetate; ingredient of metal polish; manufacture of pesticides, quinaldine, quinaline, acetophenone, etc. | Allied Chem. Corp. - Specialty Chems. Div.<br>American Cyanamid Co. - Organic Chems. Div.<br>E. I. du Pont de Nemours & Co., Inc. - Elastomer Chems. Dept. - Indust. Chems. Dept.<br>First Miss. Corp. - First Chem. Corp., subd.<br>Möbay Chem. Corp. - Indust. Chems. Div.<br>Monsanto Co. - Monsanto Indust. Chems. Co.<br>Rohm and Haas Co. - Rohm and Haas Chem. Inc. | Moundsville, W. Va.<br>Bound Brook, N. J.<br>Willow Island, W. Va.<br>Beaumont, Tex.<br>Gibbstown, N. J.<br>Pascagoula, Miss.<br>New Martinsville, W. Va.<br>Saucet, Ill.<br>Geismar, La. | 25 (55)<br>38.6 (85)<br>7.2 (50)<br>90.8 (200)<br>61.3 (135)<br>61.3 (135)<br>4.5 (10)<br>44 (74)<br>Total = 453.5 (1,000) | 250.2 (551.2) -1972                                                     |



Table A-1. (Continued)

| Chemical                  | Use <sup>1</sup>                                                                                                                                             | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                    | Location(s) <sup>2,3</sup>                                                                         | 1975 capacity <sup>2</sup><br>MM kg (MM lb.) | Total <sup>3,5</sup><br>production<br>MM kg (MM lb.)<br>for year of estimate |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------|
| Nitrobenzoic acid (m.o.p) | Organic synthesis; preparation of anesthetic & as intermediate in the manufacture of dyes & sun-screening agents                                             | Bofors Indust., Inc.<br>E. I. du Pont de Nemours & Co., Inc. - Organic Chems. Dept. - Dyes & Chems. Div.<br>Salsbury Labs.<br>Sterling Drug Inc. - The Milton-Davis Chem. Co., div.                               | Linden, N. J.<br>Deepwater, N. J.<br>Charles City, Iowa<br>Cincinnati, Ohio                        | -<br>-<br>-<br>-                             | -                                                                            |
| Nitroethane               | Propellant; solvent for nitrocellulose, cellulose acetate, tripropionate, cellulose acetobutyrate, vinyl, alkyl, waxes, fats & dyestuffs; chemical synthesis | Commercial Solvents Corp.                                                                                                                                                                                         | Stearlington, La.                                                                                  | -                                            | -                                                                            |
| Nitrotoluene              | Organic synthesis; for production of toluidine, tolidine, fuchsin, & various synthetic dyes                                                                  | E. I. du Pont de Nemours & Co., Inc. - Organic Chems. Dept. - Dyes & Chems. Div.<br>First Miss. Corp. - First Chem. Corp., subsid.                                                                                | Deepwater, N. J.<br>Pascagoula, Miss.                                                              | -<br>-                                       | -                                                                            |
| Nonene                    | Organic synthesis; wetting agent; lube oil additive; polymer gasoline                                                                                        | Atlantic Richfield Co. - ARCO Chem. Co., div.<br>Exxon Corp. - Exxon Chem. Co., div. - Exxon Chem. Co. U.S.A.<br>The Humphrey Chem. Co.<br>Sun Oil Co. - Sun Oil Co. of Penn., subsid.<br>Union Oil Co. of Calif. | East Chicago, Ind.<br>Baton Rouge, La.<br>North Haven, Conn.<br>Marcus Hook, Pa.<br>Beaumont, Tex. | -<br>-<br>-<br>-<br>-                        | -                                                                            |

Table A-1. (Continued)

| Chemical     | Usage 1                                                                                                                                                                                                         | Manufacturer, plant                                     | Location(s)                                         | 1975 capacity MM KG (KW 10) | Total 1975 production MM KG (KW 10) | for year of estimate |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------|-----------------------------|-------------------------------------|----------------------|
| Nonyl-phenol | Non-ionic surfactant (nonbiodegradable); lube oil additives; stabilizers, petroleum demulsifiers, fungicides; bactericides; dyes; drugs; adhesives; rubber chemicals; phenolic resins & plasticizers            | Borg-Warner Corp. - Western Div.                        | Morgantown, W. Va.                                  | 9.1 (20)                    | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Exxon Corp. - Exxon Chem. Co. div.                      | Bayway, N. J.                                       | 4.1 (9)                     | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Exxon Chem. Co. U.S.A. GAF Corp. - Chem. Div.           | Calvert City, Ky. Linden, N. J.                     | 2.3 (5) 9.1 (20)            | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Monanto Co. - Monanto Indust. Chems. Co.                | Kearny, N. J.                                       | 11.3 (25)                   | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Productol Chem. Co.                                     | Santa Fe Springs, Calif.                            | 1 (2)                       | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Rohm & Haas Co. - Rohm & Haas Texas Inc., subsidi.      | Philadelphia, Pa. Deer Park, Tex.                   | 9.1 (20) 2.3 (5)            | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Texaco Inc. - Jefferson Chem. Co., Inc., subsidi.       | Fort Worth, Tex.                                    | 13.5 (30)                   | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Unionroyal, Inc. - Unionroyal Chem., div.               | Naugatuck, Conn.                                    | 4.5 (10)                    | -                                   | -                    |
|              |                                                                                                                                                                                                                 | GAF Corp. - Chem. Div. Productol Chem. Co.              | Linden, N. J. Santa Fe Springs, Calif.              | -                           | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Schenectady Chems., Inc.                                | Rotterdam Junction, N. Y.                           | -                           | -                                   | -                    |
| Quin- hyd    | Substitute for acetaldehyde; rubber accelerators; rubber antioxidants; synthetic organic chemicals; dye-intermediates; medicinal; solvent for gums, resins; leather; solvent mixtures for cellulose derivatives | Rohm & Haas Co. - Rohm & Haas Texas Inc., subsidi.      | Philadelphia, Pa. Deer Park, Tex.                   | -                           | -                                   | -                    |
|              |                                                                                                                                                                                                                 | Lonza Inc. Union Carbide Corp. - Chems. & Plastics Div. | Mapleton, Ill. Institute & South Charleston, W. Va. | -                           | -                                   | -                    |
| Total =      |                                                                                                                                                                                                                 |                                                         |                                                     | 66.3 (146)                  | -                                   | -                    |

Table A-1. (Continued)

| Chemical            | Usage                                                                                                                                                          | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Location(s)                                                                                                                                                                                                | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                                                                                 | Total <sup>1,2</sup> production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Pentaerythritol     | Alkyd resins; rosin & tall oil esters; special varnishes; pharmaceuticals; plasticizers; insecticides; synthetic lubricants; explosives; paint swelling agents | Celanese Corp. - Celanese Chem. Co., div.<br>Commercial Solvents Corp.<br>Hercules Inc. - Synthetics Dept.<br>Pan American Chem. Corp.                                                                                                                                                                                                                                                                                                                                             | Slack, Tex.<br>Saffie, Pa.<br>Louisiana, Mo.<br>Toledo, Ohio                                                                                                                                               | 34 (75)<br>11.3 (25)<br>18.2 (40)<br>11.3 (25)<br>Total = 74.9 (165)                                                                                        | 46.8 (103.2) -1973                                                       |
| Pentachloroethylene | Dry cleaning solvent; vapor-degreasing solvent; drying agent for metals & certain other solids; vermifuge; heat-transfer medium, mfg. of fluorocarbons         | Diamond Shamrock Corp. - Diamond Shamrock Chem. Co. - Electrochem. Div.<br>Dow Chem. U.S.A.<br>E. I. du Pont de Nemours & Co., Inc. - Organic Chem. Dept. - Freon® Products Div.<br>Ethyl Corp.<br>Occidental Petroleum Corp. - Rucker Chem. Corp., subd. - Hooker Chem. & Plastics Corp., subd. - Electrochemical & Specialty Chems. Div.<br>PPG Indust., Inc. - Chem. Div. - Indust. Chem. Div.<br>Stauffer Chem. Co. - Indust. Chem. Div.<br>Vulcan Materials Co. - Chems. Div. | Deer Park, Tex.<br>Fresport, Tex.<br>Fresport, Calif.<br>Flaquemine, La.<br>Corpus Christi, Tex.<br>Baton Rouge, La.<br>Taft, La.<br>Lake Charles, La.<br>Louisville, Ky.<br>Jesmar, La.<br>Wichita, Kans. | 54.5 (120)<br>9.1 (20)<br>68.1 (150)<br>72.6 (160)<br>22.7 (50)<br>22.7 (50)<br>90.8 (200)<br>31.8 (70)<br>68.1 (150)<br>22.7 (50)<br>Total = 535.7 (1,180) | 332.8 (733) -1974                                                        |
| Isopentene          | Organic synthesis; blending agent for high octane motor fuel                                                                                                   | Phillips Petroleum Co. - Petrochem. & Supply Div.                                                                                                                                                                                                                                                                                                                                                                                                                                  | Phillips, Tex.                                                                                                                                                                                             | -                                                                                                                                                           | -                                                                        |

Table A-1. (Continued)

| Chemical | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                              | Manufacturer <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Location(s) <sup>3</sup>                                                                                                                                                                                                                                                                                                                                                        | 1975 capacity <sup>4</sup><br>MM KE (MM Yr.)                                                                                                                                                                                         | Total <sup>5</sup><br>Production<br>MM KE (MM Yr.)<br>for year of estimate |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| p-Terene | Polymerization inhibitor;<br>organic synthesis                                                                                                                                                                                                                                                                                                  | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | -                                                                                                                                                                                                                                                                                                                                                                               | -                                                                                                                                                                                                                                    | -                                                                          |
| o-Terene | Manufacture of dyes;<br>laboratory reagent                                                                                                                                                                                                                                                                                                      | Monsanto Co. - Monsanto<br>Indust. Chem. Co.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | St. Louis, Mo.                                                                                                                                                                                                                                                                                                                                                                  | -                                                                                                                                                                                                                                    | -                                                                          |
| p-Terene | Dye stuffs intermediates;<br>pharmaceuticals; medi-<br>cine; laboratory<br>reagent                                                                                                                                                                                                                                                              | Monsanto Co. - Monsanto<br>Indust. Chem. Co.<br>Salsbury Labs.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | St. Louis, Mo.<br>Sauget, Ill.<br>Wilmington, N. C.                                                                                                                                                                                                                                                                                                                             | -                                                                                                                                                                                                                                    | -                                                                          |
| Phenol   | Phenolic resins; epoxy<br>resins (bisphenol-A);<br>nylon-6 (caprolactam);<br>2,4-D; selective solvent<br>for refining lubricating<br>oils; adipic acid; sal-<br>icylic acid; phenolphtha-<br>lein; pentachlorophenol;<br>acetophenone; picric<br>acid; germicide; phar-<br>maceuticals; labora-<br>tory reagent; dyes &<br>indicators; silicide | Allied Chem. Corp. -<br>Specialty Chem. Div.<br>Clark Oil & Refining<br>Corp. - Clark Chem.<br>Corp., subd.<br>Dow Chem. U.S.A.<br>Georgia-Pacific Corp. -<br>Chem. Div.<br>Kalamazoo Chem. Inc.<br>Koppers Co., Inc. -<br>The Merichem Co.<br>Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.<br>Productol Chem. Co.<br>Reichhold Chem., Inc.<br>Swelly Oil Co.<br>Standard Oil Co. of<br>Calif. - Chevron Chem.<br>Co., subd. - Brenite<br>Additives & Indust.<br>Chem. Div. - Indust.<br>Chem.<br>Stinson Lumber Co. -<br>Northwest Petrochem.<br>Corp., div.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. -<br>Union Carbide Chem.<br>Inc., subd.<br>U.S. Steel Corp. - 188<br>Chem., div. | Frankford, Pa.<br>Blue Island, Ill.<br>Midland, Mich.<br>Oyster Creek, Tex.<br>Piquemine, La.<br>Kalamazoo, Wash.<br>Rollanston, W. Va.<br>Houston, Tex.<br>Chocolate Bayou,<br>Tex.<br>Santa Fe Springs,<br>Calif.<br>Tuscaloosa, Ala.<br>El Dorado, Kans.<br>Richmond, Calif.<br>Anacortes, Wash.<br>Round Rock, N. J.<br>Pensacola, F. R.<br>Clinton, Pa.<br>Haverhill, Ohio | 238.3 (525)<br>40 (88)<br>45.4 (100)<br>181.6 (400)<br>130.3 (287)<br>25 (55)<br>-<br>-<br>204.3 (450)<br>-<br>61.3 (135)<br>43.1 (96)<br>25 (66)<br>-<br>63.1 (100)<br>90.8 (200)<br>-<br>127.1 (280)<br>Total =<br>1,280.3 (1,610) |                                                                            |

Table A-1. (Continued)

| Chemical                             | Usage <sup>1</sup>                                                                                                                                                                                                                                            | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                  | Location(s) <sup>3,4</sup>                                                                                                                                                      | 1975<br>capacity <sup>2</sup><br>MM Kg (MM lb) | Total <sup>4,5</sup><br>production<br>MM Kg (MM lb)<br>for year of estimate |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| Phenol-<br>sulfonic<br>acids         | Water analysis; laboratory reagent; electrolyte; plastic; catalyst; dyes; intermediates or pharmaceuticals                                                                                                                                                    | Productol Chem. Co.<br>Jim Walter Corp. - U.S.<br>Pipe & Foundry Co.<br>subsidi. - Chem. Div.<br>Witco Chem. Corp. -<br>Ultra Div.<br>Sterling Drug Inc. -                                                                                                                                                                                                                                                                                      | Santa Fe Springs,<br>Calif.<br>Birmingham, Ala.<br>Paterson, N. J.<br>Rensselaer, N. Y.                                                                                         | -<br>-<br>-<br>-                               | -                                                                           |
| Phenyl-<br>anthra-<br>quinic<br>acid | -                                                                                                                                                                                                                                                             | -                                                                                                                                                                                                                                                                                                                                                                                                                                               | -                                                                                                                                                                               | -                                              | -                                                                           |
| Phenylene-<br>diamine                | Azo dye intermediate; photographic development; fur dyes; photochemical measure-<br>ments; intermediate in manufacture of antioxidants & accelerators for rubbers; detection of nitrous acid; textile developing agent; organic synthesis; laboratory reagent | Fairmount Chem. Co.,<br>The Sherwin-Williams<br>Co. - Sherwin-Williams<br>Chem. Div.<br>Toms River Chem. Corp.<br>E. I. du Pont de Nemours & Co., Inc. -<br>Organic Chem. Dept. -<br>Dyes & Chem. Div.<br>The B. F. Goodrich<br>Co. - B. F. Goodrich<br>Chem. Co., div.<br>Martin Marietta Corp. -<br>Martin Marietta Chem.<br>Sodyco Div.<br>Ashland Oil, Inc. -<br>Ashland Chem. Co., div. -<br>Chem. Products Div.<br>GAP Corp. - Chem. Div. | Deepwater, N. J.<br>Newark, N. J.<br>St. Bernard, Ohio<br>Toms River, N. J.<br>Deepwater, N. J.<br>Henry, Ill.<br>Sodyco, N. C.<br>Great Meadows,<br>N. J.<br>Rensselaer, N. Y. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-           | 29.1 (64) -1971                                                             |

Table A-1. (Continued)

| Chemical | Usage                                                                                                                                                                              | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Location(s)                                                                                                                                                                                                                                                                                                                                                                              | 1975 capacity<br>MM kg (MM lb)                                                                                                                                                                                                   | Total 1975<br>production<br>MM kg (MM lb)<br>for year of estimate |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| Phosgene | Organic synthesis, esters, alcohols, isocyanates, polycarbonate resins, carbamate resins, carbamates, organic carbamates & chloroformates; pesticides; herbicides; dye manufacture | Allied Chem. Corp. - Specialty Chem. Div.<br>BASF Wyandotte Corp. - Indust. Chems. Group<br>Chematron Corp. - Chems. Group - Organic Chems. Div.<br>E. I. du Pont de Nemours & Co., Inc. - Elastomer Chems. Dept.<br>PMC Corp. - Chem. Group - Indust. Chem. Div.<br>Gen. Electric Co. - Plastics Business Div. - Engineering Plastics Product Dept.<br>Möbly Chem. Corp. - Indust. Chems. Div.<br>Olin Corp. - Agricultural Chems. Div. - Designed Products Div.<br>PPG Indust., Inc. - Chem. Div. - Indust. Chem. Div.<br>Rubicon Chems. Inc.<br>Stauffer Chem. Co. - Agricultural Chem. Div.<br>Story Chem. Corp. - Ott Div.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subd.<br>Union Carbide Corp. - Chems. & Plastics Div.<br>The Upjohn Co. - Polymer Chems. Div.<br>Van De Mark Chem. Co., Inc. | Mountville, Pa.<br>Belmar, N.J.<br>La Porte, Tex.<br>Deshwater Point, N. J.<br>Baltimore, Md.<br>Mount Vernon, Ind.<br>Cedar Bayou, Tex.<br>New Martinsville, W. Va.<br>Lake Charles, La.<br>Ashtabula, Ohio<br>Barberton, Ohio<br>Geismar, La.<br>Cold Creek, Ala.<br>Muskegon, Mich.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va.<br>La Porte, Tex.<br>Lockport, N. Y. | 44.5 (98)<br>25 (55)<br>9.1 (20)<br>61.3 (135)<br>2.7 (6)<br>27.2 (60)<br>50 (110)<br>111.2 (245)<br>54.5 (120)<br>23.7 (50)<br>7.3 (5)<br>56.7 (125)<br>11.3 (25)<br>4.5 (10)<br>13.6 (30)<br>50 (110)<br>90.8 (200)<br>3.6 (8) | 330.6 (728.2) -1973                                               |
|          |                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                          | Total =                                                                                                                                                                                                                          | 650.1 (1,427)                                                     |

Table A-1. (Continued)

| Chemical           | Usage <sup>1</sup>                                                                                                                                                                                                                                    | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                         | 1975 capacity <sup>2</sup><br>MM KG (MM lb.)                                                                                                                                         | Total <sup>4</sup><br>production<br>MM KG (MM lb.)<br>for year of estimate |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Phthalic anhydride | Alkyd resins; plasticizers; hardener for resins; polyester; synthesis of phthalic acid; other phthalates, many other uses; chlorinated products; pharmaceutical intermediates; insecticides; diethyl phthalate; diethyl phthalate; laboratory reagent | Alcoa Chem. Corp. -<br>Phthalic Anhydride Div.<br>BASF Wyandotte Corp. -<br>Phthalic Anhydride Div.<br>EXXON CORP. - EXXON<br>Chem. Co., div. - EXXON<br>Chem. Co., U.S.A.<br>Koppers Co., Inc. -<br>Organic Materials Div.<br>Monsanto Co. -<br>Monsanto Chem. Co.<br>Occidental Petroleum Corp. -<br>Occidental Chem. Corp. -<br>Hooker Chem. & Plastics Corp.<br>Solutia -<br>Solutia -<br>Solutia -<br>Standard Oil Co. of<br>Calif. -<br>Chevron Chem. Co.,<br>Additives & Indust. Chem. Div. -<br>Indust. Chem.<br>Stepan Chem. Co. -<br>Surfactant Dept.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>U.S. Steel Corp. -<br>USS | El Segundo, Calif.<br>South Kearny, N. J.<br>Eaton Rouge, La.<br>Bridgeville, Pa.<br>Cicero, Ill.<br>Bridgeport, N. J.<br>Texas City, Tex.<br>Aresibo, P. R.<br>Richmond, Calif.<br>Anaheim, Calif.<br>Elwood, Ill.<br>Fieldstone, N. J.<br>Institute & South<br>Charleston, W. Va.<br>Neville Island, Pa.<br>St. Bernard,<br>Ohio | 15.0 (35)<br>59 (130)<br>40.9 (90)<br>40.9 (90)<br>59 (130)<br>38.6 (85)<br>59 (130)<br>45.4 (100)<br>22.7 (50)<br>22.7 (50)<br>45.4 (100)<br>68.1 (150)<br>Total =<br>517.6 (1,140) | 444.6 (973) -1974                                                          |
| Phthalimide        | Synthetic indigo, via anthranilic acid; fungicide; organic synthesis; laboratory reagent                                                                                                                                                              | The Sherwin-Williams Co. -<br>Sherwin-Williams Chem. Div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | St. Bernard,<br>Ohio                                                                                                                                                                                                                                                                                                               | -                                                                                                                                                                                    | -                                                                          |

Table A-1. (Continued)

| Chemical            | Usage                                                                                                                                                                                                                                                | Manufacturer(s) (2-3)                                                                                                                                                                                                                                                                                                            | Location(s) (2-3)                                                                                                                                        | Capacity,<br>MM KG (MM lb)<br>Per year of estimate           | Total, %<br>Production<br>MM KG (MM lb)<br>Per year of estimate |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------|
| Phthalonitrile      | Intermediate in organic synthesis, especially pigments & dyes; base material for high temperature lubricants & coatings; insecticide                                                                                                                 | -                                                                                                                                                                                                                                                                                                                                | -                                                                                                                                                        | -                                                            | -                                                               |
| Piperazine          | Corrosion inhibitor; synthetic insecticide; accelerator for curing polychloroprene                                                                                                                                                                   | Fleming Labs., Inc.<br>- Lago Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.                                                                                                                                                                                                          | Charlotte, N. C.<br>Conroe, Tex.<br>Tart, La.<br>Texas City, Tex.                                                                                        | -<br>-<br>-<br>-                                             | -<br>-<br>-<br>-                                                |
| Polybutenes         | Hot-melt adhesives; sealing tapes; special sealants; cable insulation; polymer modifier; viscosity index improvers; lure oil additive                                                                                                                | American Petrofina, Inc. - Cosden Oil & Chem. Co., subsid.<br>Exxon Corp. - Exxon Chem. Co., div. - Exxon Chem. Co. U.S.A.<br>The Lubrizol Corp.<br>Standard Oil Co. of Calif. - Chevron Chem. Co., subsid. - Oronite Additives & Indust. Chems. Div. - Indust. Chems.<br>Standard Oil Co. (Ind.)<br>Amoco Chems. Corp., subsid. | Big Spring, Tex.<br>Bayway, N. J.<br>Deer Park, Tex.<br>Richmond, Calif.<br>Texas City, Tex.<br>Wood River, Ill.                                         | 21,120<br>20,000,000<br>20,000<br>20,000<br>77,000<br>20,000 | 104.4 (230) - 1967                                              |
| Polyethylene glycol | Chemical intermediates (lower molecular weight varieties); plasticizer; softeners & humectants; lubricants; bases for cosmetics & pharmaceuticals; solvents; tinners; metal & rubber processing; emulsifying agents; animal feed; laboratory reagent | Ashland Oil, Inc. - Ashland Chem. Co., div. - Chem. Products Div.<br>BASF Wyandotte Corp. - Indust. Chems. Group<br>Dow Chem. U.S.A.<br>Hodag Chem. Corp.<br>Olin Corp. - Designed Products Div.<br>Texaco Inc. - Jefferson Chem. Co., Inc., subsid.<br>Union Carbide Corp. - Chems. & Plastics Div.                             | Janesville, Wisc.<br>Wyandotte, Mich.<br>Freeport, Tex.<br>Skokie, Ill.<br>Brandenburg, Ky.<br>Port Neches, Tex.<br>Institute & South Charleston, W. Va. | -<br>-<br>-<br>-<br>-<br>-<br>-                              | 208.6 (460)                                                     |





Table A-1. (Continued)

| Chemical                      | Usage                                                                                                                                                                    | Manufacturer(s) (2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Location(s) (2,3)                                                                                                                                                                                                                                                                                                           | Capacity <sup>2</sup><br>MM BBL/ANNUM (1) | 1975<br>Production<br>MM BBL (ANNUM)<br>for year of estimate | Total, \$ |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|--------------------------------------------------------------|-----------|
| Poly-ethylene glycol chloride | Solvents for cleaning extracting, & demulsifying                                                                                                                         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -                                                                                                                                                                                                                                                                                                                           | -                                         | -                                                            | -         |
| Polypropylene glycol          | Hydraulic fluids; rubber lubricants; antifouling agents; intermediates for adhesives, coatings, dyes; elastomers; plasticizers; paint formulations; laboratory reagent   | SAR, Wyandotte Corp. -<br>Chems. Group<br>E. S. Carpenter Co.,<br>Inc. - Chate Chem.<br>Co., subd.<br>Dow Chem. U.S.A.<br>Borg Chem. Corp.<br>The United States Inc.<br>Specialty Chems. Div.<br>Valco Chem. Co.<br>Carbide & Process<br>Chem. Div. - Visco<br>Chems.<br>Valco Corp. - Designed<br>Products Div.<br>Petrol Corp. - Texaco<br>Inc. - Jefferson Chem.<br>Co., subd.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>Valco Chem. Corp. -<br>Specialty Div.<br>Air Products & Chems.<br>Inc. - Specialty Gas -<br>Corp. - Chems. &<br>Intermediates Mktg.<br>Mannchem Gas Products<br>Louisiana Petroleum Co.<br>Petroleum & Supply<br>Co. - Member Ser-<br>vice Center<br>Specialty Petroleum Co. | Washington, N. J.<br>Wyandotte, Mich.<br>Bayport, Tex.<br>Freeport, Tex.<br>Midland, Mich.<br>Stockie, Ill.<br>New Castle, Del.<br>Sugar Land, Tex.<br>Brandenburg, Ky.<br>Conroe, Tex.<br>Institute & South<br>Charleston, W. Va.<br>Clearing, Ill.<br>Allentown, Pa.<br>Lyndhurst, N. J.<br>Berger, Tex.<br>Chicago, Ill. | 35.5 (85.5) - 1973                        | 21,802 (48,022) - 1971                                       |           |
| Propane                       | Organic synthesis; household & industrial fuel; manufacture of ethylene; extractant; solvent; refrigerant; gas enricher; aerosol propellant; mixture for bubble chambers | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | -                                                                                                                                                                                                                                                                                                                           | -                                         | -                                                            | -         |

Table A-1. (Continued)

| Chemical                          | Usage                                                                                                                                                                                                                                                                                                                             | Manufacturer(s)                                                                                                                                                                                                                                                                         | Location(s)                                                                                                                                                                                                                               | 1975 capacity, <sup>2</sup><br>MM kg. (MM lb.)                                                                                                   | Total <sup>1</sup> production,<br>MM kg. (MM lb.)<br>for year of estimate |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Propylene<br>oxide                | Manufacture of poly-<br>vinyl acetals & other<br>plastics; synthesis<br>of rubber chemicals;<br>disinfectant;<br>preservative                                                                                                                                                                                                     | Eastman Kodak Co. -<br>Inc., subd.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                                                                                                                                    | Longview, Tex.<br>Seadrift, Tex.<br>Texas City, Tex.                                                                                                                                                                                      | -<br>-<br>-                                                                                                                                      | -                                                                         |
| Potassium<br>permanganate<br>acid | Propionates, some of<br>which are used as mold<br>inhibitors in bread &<br>fungicides in general;<br>emulsifying agents;<br>solutions for electro-<br>plating nickel; per-<br>fume esters; artificial<br>fruit flavors; pharma-<br>ceuticals; solvent mix-<br>tures for cellulose<br>derivatives; pretreat-<br>ment of zinc oxide | Celanese Corp. -<br>Commercial Solvents Corp.<br>Eastman Kodak Co. -<br>Inc., subd. - Tenn.<br>Eastman Chem. Products<br>Eastman Co., div.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                                                                                            | Pampa, Tex.<br>Sterlington, La.<br>Kingsport, Tenn.<br>Institute & South<br>Charleston, W. Va.                                                                                                                                            | 5.4 (12)<br>1.4 (3)<br>9.1 (20)<br>11.3 (25)<br>Total =<br>27.2 (60)                                                                             | 27.2 (60.4) -1973                                                         |
| Propyl-<br>amine                  | Intermediate; laboratory<br>reagent                                                                                                                                                                                                                                                                                               | Penwalt Corp. - Chem.<br>Div.<br>Va. Chem. Inc. - Indust.<br>Chem. Dept.<br>Fublicker Indust. Inc.                                                                                                                                                                                      | Wyandotte, Mich.<br>Fortsomouth, Va.<br>Philadelphia, Pa.                                                                                                                                                                                 | -<br>-<br>-                                                                                                                                      | 7.6 (16.7) -1972                                                          |
| Propyl<br>chloride                | Solvent; intermediate<br>propylamine                                                                                                                                                                                                                                                                                              | Amerasia Hess Corp.<br>American Petrochem.<br>Inc. - Corden Oil &<br>Chem. Co., subd.<br>ARCO/Polymers, Inc.<br>Ashland Oil, Inc. -<br>Ashland Chem. Co., div.,<br>Petrochem. Div.<br>Atlantic Richfield Co. -<br>ARCO Chem. Co., div.<br>BASF Wyandotte Corp. -<br>Indust. Chem. Group | Fort Reading, N. J.<br>Big Spring, Tex.<br>Eldorado, Tex.<br>Mount Pleasant, Tex.<br>Houston, Tex.<br>Ashland, Ky.<br>Louisville, Ky.<br>North Tonawanda<br>Channelview, Tex.<br>East Chicago, Ind.<br>Wilmington, Calif.<br>Geismar, La. | 59 (130)<br>59 (130)<br>15 (33)<br>25 (55)<br>68.1 (150)<br>75 (165)<br>13.6 (30)<br>22.7 (50)<br>6.8 (15)<br>30 (66)<br>45.4 (100)<br>22.7 (50) | 3,584 (10,010) -1974                                                      |

Table A-1. (Continued)

| Chemical              | Plant 1<br>(See previous page) | Manufacturer(s) (2)                                                                                                                              | Location (1)                                                         | 1975<br>capacity,<br>MM kg (MM lb)                  | Total 1975<br>production,<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-----------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------------|
| Propylene<br>(cont'd) |                                |                                                                                                                                                  |                                                                      |                                                     |                                                                                           |
|                       |                                | The Charter Co. -<br>Charter Oil Co.,<br>Dallas, Tex. -<br>Charter<br>International Oil Co.,<br>subsidiary.                                      | Houston, Tex.                                                        | 34 (75)                                             |                                                                                           |
|                       |                                | Chemplex Co.<br>Cities Service Co.,<br>Inc. - North American<br>Petroleum Group<br>Clark Oil & Refining<br>Corp., Clark Chem.<br>Corp., subsidi. | Clinton, Iowa<br>Lake Charles, La.<br><br>Blue Island, Ill.          | 61.3 (135)<br>240.6 (530)<br><br>20.4 (45)          |                                                                                           |
|                       |                                | Coastal States Gas<br>Corp. - Coastal<br>States Marketing,<br>Inc., subsidi.                                                                     | Corpus Christi, Tex.                                                 | 25 (55)                                             |                                                                                           |
|                       |                                | Continental Oil Co. -<br>Conoco Chem.                                                                                                            | Westlake, La.                                                        | 18.2 (40)                                           |                                                                                           |
|                       |                                | Dow Chem. U.S.A.                                                                                                                                 | Bay City, Mich.<br>Freeport, Tex.<br>Plaquemine, La.<br>Orange, Tex. | 45.4 (100)<br>235 (440)<br>72.6 (160)<br>68.1 (150) |                                                                                           |
|                       |                                | E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Plastics Dept.                                                                                    | Longview, Tex.                                                       | 136.2 (300)                                         |                                                                                           |
|                       |                                | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subsidi. - Texas<br>Eastman Co., div.                                                    | Odessa, Tex.                                                         | 70.3 (175)                                          |                                                                                           |
|                       |                                | El Paso Natural Gas<br>Co., El Paso Products<br>Co., subsidi.                                                                                    | Baton Rouge, La.<br>Baytown, Tex.<br>Bayway, N. Y.                   | 710.5 (1,565)<br>740.7 (1,630)<br>146.3 (320)       |                                                                                           |
|                       |                                | Exxon Corp. - Exxon<br>Chem. Co., div. -<br>Exxon Chem. Co. U.S.A.                                                                               | Delaware City,<br>Calvert City, Ky.                                  | 91.7 (180)<br>63.6 (140)                            |                                                                                           |
|                       |                                | Getty Oil Co.<br>The R. F. Goodrich<br>Chem. Co., div.                                                                                           | Cedar Rapids, Tex.<br>Fritch, Tex.<br>Fort Arthur, Tex.              | 56.7 (125)<br>84.1 (185)<br>26.7 (59)               |                                                                                           |
|                       |                                | Gulf Oil Corp. -<br>Gulf Oil Chem. Co.,<br>div. - Petrochems. Div.                                                                               | Georgetown, Mich.<br>Texas City, Tex.<br>Beaumont, Tex.              | 14.4 (100)<br>130.8 (290)<br>220.7 (490)            |                                                                                           |
|                       |                                | Marathon Oil Co.                                                                                                                                 |                                                                      |                                                     |                                                                                           |

Table A-1. (Continued)

| Chemical              | Usage <sup>1</sup>  | Manufacturer(s) <sup>2,3</sup>                                                                                                    | Location(s) <sup>4,5</sup> | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>6,7</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-----------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------------------|----------------------------------------------------------------------------------------------------|
| Propylene<br>(cont'd) | (See previous page) |                                                                                                                                   |                            |                                             |                                                                                                    |
|                       |                     | Mobil Oil Corp. -<br>Mobil Chem. Co., div. -<br>Petrochem. Div.                                                                   | Beaumont, Tex.             | 220.2 (485)                                 |                                                                                                    |
|                       |                     | Monsanto Co. - Monsanto<br>Polymers & Petrochems.<br>Co.                                                                          | Chocolate Bayou,           | 250 (550)                                   |                                                                                                    |
|                       |                     | Northern Natural Gas<br>Co. - Northern Petr-<br>chem. Co. subd. -<br>Polymers Div.                                                | Morris, Ill.               | 90.8 (200)                                  |                                                                                                    |
|                       |                     | Novacort Corp.                                                                                                                    | Kenova, W. Va.             | 84 (185)                                    |                                                                                                    |
|                       |                     | The Oil Shale Corp. -<br>Lion Oil Co., subd.                                                                                      | El Dorado, Ark.            | -                                           |                                                                                                    |
|                       |                     | Petro Gas Producing Co.                                                                                                           | Groves, Tex.               | 25 (55)                                     |                                                                                                    |
|                       |                     | Phillips Petroleum Co.                                                                                                            | Fenuelas, P. R.            | 68.1 (150)                                  |                                                                                                    |
|                       |                     | Puerto Rico Olefins Co.                                                                                                           | Sweeny, Tex.               | 295.1 (650)                                 |                                                                                                    |
|                       |                     | Shell Chem. Co. -<br>Fase Chem.                                                                                                   | Deer Park, Tex.            | 499.4 (1,100)                               |                                                                                                    |
|                       |                     | Skelly Oil Co.                                                                                                                    | Dominguez, Calif.          | 79.5 (175)                                  |                                                                                                    |
|                       |                     | Standard Oil Co. of<br>Calif. - Chevron Chem.<br>Co., subd. - Oronite<br>Co., subd. - Additives<br>Chem. Div. -<br>Indust. Chems. | Norco, La.                 | 100 (220)                                   |                                                                                                    |
|                       |                     | Standard Oil Co. (Ind.) -<br>Amoco Chem. Corp.,<br>subd.                                                                          | El Dorado, Kans.           | 11.8 (26)                                   |                                                                                                    |
|                       |                     | The Standard Oil Co.<br>(Ohio)                                                                                                    | El Segundo, Calif.         | 18.2 (40)                                   |                                                                                                    |
|                       |                     | Sun Oil Co. - Sun Oil<br>Co. of Penn., subd.                                                                                      | Richmond, Calif.           | 93.1 (206)                                  |                                                                                                    |
|                       |                     | Surridge Refining Co.,<br>subd.                                                                                                   | Chocolate Bayou,<br>Tex.   | 179.3 (395)                                 |                                                                                                    |
|                       |                     |                                                                                                                                   | Texas City, Tex.           | 172.5 (380)                                 |                                                                                                    |
|                       |                     |                                                                                                                                   | Wood River, Ill.           | 50 (110)                                    |                                                                                                    |
|                       |                     |                                                                                                                                   | Lima, Ohio                 | 81.7 (180)                                  |                                                                                                    |
|                       |                     |                                                                                                                                   | Toledo, Ohio               | 88.5 (195)                                  |                                                                                                    |
|                       |                     |                                                                                                                                   | Duncan, Okla.              | 36.3 (80)                                   |                                                                                                    |
|                       |                     |                                                                                                                                   | Marcus Hook, Pa.           | 154.8 (340)                                 |                                                                                                    |
|                       |                     |                                                                                                                                   | Toledo, Ohio               | 25 (55)                                     |                                                                                                    |
|                       |                     |                                                                                                                                   | Corpus Christi,<br>Tex.    | 91 (200)                                    |                                                                                                    |

Table A-1. (Continued)

| Chemical                       | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                      | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                          | Location(s) <sup>2,3</sup>                                                                                                                                                                                   | 1975 capacity:<br>MM kg (MM lb.)                                                                                                             | Total <sup>4,5</sup><br>production<br>MM kg (MM lb.)<br>for year of estimate |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Propylene<br>oxide<br>(cont'd) | (See previous page)                                                                                                                                                                                                                                                                                                                     | Texaco Inc.<br>Jefferson Chem. Co.,<br>Inc., subd.<br>Texas City Refining<br>Inc.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>Union Carbide Caribe,<br>Union Oil Co. of Calif. | Port Arthur, Tex.<br>Westville, N. J.<br>Port Neches, Tex.<br>Texas City, Tex.<br>Seadrift, Tex.<br>Tart, La.<br>Texas City, Tex.<br>Torrance, Calif.<br>Whiting, Ind.<br>Pensacola, P. R.<br>Beaumont, Tex. | 11.3 (25)<br>25 (55)<br>59 (130)<br>45.1 (100)<br>50 (110)<br>109 (240)<br>125 (275)<br>206.8 (455)<br>3.1 (68)<br>Total =<br>6,751 (14,870) | (See previous page)                                                          |
| Propylene<br>chloro-<br>hydrin | Organic synthesis<br>(introducing hydroxy-<br>propyl group)                                                                                                                                                                                                                                                                             | Eastman Kodak Co. -<br>Eastman Organic Chem.                                                                                                                                            | Rochester, N. Y.                                                                                                                                                                                             | -                                                                                                                                            | -                                                                            |
| Propylene<br>dichloride        | Intermediate for per-<br>chloroethylene &<br>carbon tetrachloride;<br>lead scavenger for<br>antiknock for gas;<br>solvents for fats,<br>celluloses, gums, &<br>resins; solvent mix-<br>tures for cellulose<br>esters & ethers;<br>scouring compounds;<br>spotting agents; metal<br>degreasing agents;<br>soil fumigant for<br>nematodes | Dow Chem. U.S.A.<br>Olin Corp. - Designed<br>Products Div.<br>Texaco Inc. - Jefferson<br>Chem. Co., Inc., subd.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.                       | Freeport, Tex.<br>Plaquemine, La.<br>Brandenburg, Ky.<br>Port Neches, Tex.<br>Institute & South<br>Charleston, W. Va.                                                                                        | 11.3 (25)<br>4.5 (10)<br>-<br>6.8 (15)<br>11.3 (25)<br>Total =<br>315.5 (695)                                                                | -                                                                            |
| Propylene<br>oxide             | Propylene glycol &<br>other glycols; urethane<br>foams, surfactants &<br>detergents; copolymer<br>adhesives; fumigant; syn-<br>thetic elastomer<br>(homopolymer)                                                                                                                                                                        | BASF Wyandotte Corp. -<br>Indust. Chem. Group<br>Dow Chem. U.S.A.<br>Olin Corp. - Designed<br>Products Co.<br>Olin Corp. Chem. Co.<br>Texaco Inc. - Jefferson<br>Chem. Co., Inc., subd. | Wyandotte, Mich.<br>Freeport, Tex.<br>Plaquemine, La.<br>Brandenburg, Ky.<br>Bayport, Tex.<br>Port Neches, Tex.                                                                                              | 79.8 (175)<br>340.5 (750)<br>100 (220)<br>59 (130)<br>404 (890)<br>68.1 (150)<br>Total =<br>1,051 (2,310)                                    | 308 (1,780) -1974                                                            |

Table A-1. (Continued)

| Commodity                      | Use:                                                                                                                                                                | Manufacturer(s)                                                                                                                                                                                                                                                                                                                            | Location(s)                                                                                                                                          | 1975 capacity, <sup>2</sup> MM kg. (MM lb.)                                   | Total <sup>1,3</sup> production MM kg. (MM lb.) for year of estimate |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Pyridine (natural & synthetic) | Synthesis of vitamins & drugs; solvent; water-proofing; rubber chemicals; denaturant for alcohol; antifreeze mixtures; dyeing assistant in textiles; fungicides     | Natural: Crowley Tar Products, Inc.<br>Koppers Co., Inc. - Organic Materials Div.<br>Synthetic: Reilly Tar & Chem. Corp.<br>Warner-Lambert Co. - Nepers Chem. Co., Inc., subsid.<br>Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn. Eastman Co., div.<br>Frank Enterprises<br>Koppers Co., Inc. - Organic Materials Div. | Baltimore, Md.<br>Houston, Tex.<br>Pellaussee, W. Va.<br>Indianapolis, Ind.<br>Harriman, N. Y.<br>Kingsport, Tenn.<br>Columbus, Ohio<br>Petroia, Pa. | -<br>-<br>-<br>16 (35)<br>2.3 (5)<br>-<br>-<br>11.3 (25)<br>Total = 11.3 (25) | 3.4 (7.42) -1968                                                     |
| Quinone                        | Mfg. of dyes & hydroquinone                                                                                                                                         | Eastman Kodak Co. - Eastman Chem. Products, Inc., subsid. - Tenn. Eastman Co., div.<br>Frank Enterprises<br>Koppers Co., Inc. - Organic Materials Div.                                                                                                                                                                                     | Kingsport, Tenn.<br>Columbus, Ohio<br>Petroia, Pa.                                                                                                   | -<br>-<br>11.3 (25)<br>Total = 11.3 (25)                                      | -<br>-<br>11.8 (26) -1970                                            |
| Resorcinol                     | Resorcinol-formaldehyde resins; dyes; pharmaceuticals; rubber-tackifier; adhesives for wood veneers & rubber-to-textile composites; medicine; mfg. of styphnic acid | Aldrich Chem. Co., Inc.<br>Koppers Co., Inc. - Organic Materials Div.                                                                                                                                                                                                                                                                      | Milwaukee, Wisc.<br>Petroia, Pa.                                                                                                                     | -<br>-                                                                        | -                                                                    |
| Resorcinol                     | Mfg. of aspirin & other medicinal; preservative; dyes; perfumes; vulcanization inhibitor; organic intermediate; fungicide                                           | Dow Chem. U.S.A.<br>Monsanto Co. - Monsanto Indust., Chems. Co.                                                                                                                                                                                                                                                                            | Midland, Mich.<br>St. Louis, Mo.                                                                                                                     | 7.7 (17)<br>9.1 (20)                                                          | 6.2 (13.6) -1969                                                     |

Table A-1. (Continued)

| Chemical                                  | Use <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                  | Manufacturer(s) <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                       | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                              | Total <sup>4</sup><br>production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Salt-<br>sulfate<br>acid<br>(cont'd)      | (See previous page)                                                                                                                                                                                                                                                                                                                                               | Stevling Drug Inc. -<br>The Hilton-Davis<br>Chemical Co., div.<br>Tenneco Inc. - Tenneco<br>Chemicals, Inc. - Tenneco<br>Organics & Polymers<br>Div.                                                                                                                                                                                                                                                                                                                                                                                            | Cincinnati, Ohio<br>Jaffield, N. J.                                                                                                                                                                                                                                                              | 3.2 (7)<br>4.5 (10)                                                                      |                                                                                                  |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   | Allied Chem. Corp. -<br>Specialty Chems. Div.<br>Dan River, Inc.<br>Howerton Owen Chems.,<br>Inc.<br>Wallachrodt, Inc. -<br>Indus. Chems. Div.<br>Washline Div.<br>Ritter Chem. Co., Inc.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.<br>BASF Wyandotte Corp. -<br>Indus. Chems. Group<br>Brown Co.<br>Hercules Inc. - Coatings<br>& Specialty Products<br>Dept.<br>H. Kohnstamm & Co.,<br>Inc.<br>The Procter & Gamble<br>Co. - The Buckeye Cel-<br>lulose Corp., subd.<br>United Aircraft Corp. -<br>Essex Internat'l Inc.,<br>subs'd. | Marcus Hook, Pa.<br>Danville, Va.<br>Racine Rapids,<br>N. C.<br>St. Louis, Mo.<br>Lodi, N. J.<br>Amsterdam, N. Y.<br>Niagara Falls,<br>N. Y.<br>Wyandotte, Mich.<br>Berlin, N. H.<br>Hartford Beach, Mich.<br>Hopewell, Va.<br>Camden, N. J.<br>Clearing, Ill.<br>Memphis, Tenn.<br>Muncie, Ind. | 1.8 (4.0)<br>4.5 (10.0)<br>18 (40.0)<br>0.9 (2.0)<br>0.5 (1.0)<br>3.2 (7.0)<br>1.1 (2.5) | 29.5 (64.9) -1970                                                                                |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                  | Total =<br>24.5 (54)                                                                     |                                                                                                  |
| Sodium<br>acetate                         | Dye & color intermedi-<br>ate; pharmaceuticals;<br>cinnamic acid; soaps;<br>photography; purifica-<br>tion of glucose; meat<br>preservation; medicine;<br>electroplating; tanning;<br>dehydrating agent; buf-<br>fer in foods; laboratory<br>reagent                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                  |                                                                                          |                                                                                                  |
| Sodium<br>carboxy-<br>methyl<br>cellulose | Detergents, soaps, food<br>products (especially<br>dietetic foods & ice<br>cream), where it acts as<br>water binder, thickener,<br>suspending agent, emul-<br>sion stabilizer, textile<br>manufacturing (sizing),<br>coating paper & paper<br>board to lower porosity;<br>drilling muds; emulsion<br>paints; protective<br>colloid; pharmaceuticals;<br>cosmetics |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                  |                                                                                          |                                                                                                  |
|                                           |                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                  | Total =<br>30.2 (66.5)                                                                   |                                                                                                  |

Table A-1. (Continued)

| Chemical       | Use <sup>1</sup>                                                                                                                                                        | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                          | 1975 capacity <sup>2</sup><br>MM KG (MM lb)                             | Total <sup>3,4</sup><br>production<br>MM KG (MM lb)<br>for year of estimate |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Sodium formate | Reducing agent;<br>medicine; manufacture of<br>citric acid & oxalic<br>acid; organic chemicals;<br>resins; coatings; wall-<br>paper printing; plating                   | Commercial Solvents<br>Corp.<br>Hercules Inc. -<br>Synthetic Dept.<br>Pan American Chem.<br>Corp.<br>Tenneco Inc. - Tenneco<br>Chemicals, Inc. -<br>Organics & Polymers Div.<br>American Petrofina, Inc. -<br>American Petrofina Co.<br>of Texas, subsid.<br>Cott Indust., Inc. -<br>Crucible Stainless Steel<br>& Alloy Div.<br>National Steel Corp. -<br>Great Lakes Steel Div. -<br>B. F. Div.<br>Republic Steel Corp. -<br>Iron & Chem. Div.<br>Sharon Steel Corp. -<br>Fairmont Coke Works<br>Shenango Inc.<br>Wheeling-Pittsburgh<br>Steel Corp.<br>American Hoechst Corp. -<br>Dyes & Pigments Div.<br>Pfizer Inc. -<br>Chems. Div. | Seitz, Pa.<br>Louisiana, Mo.<br>Toledo, Ohio<br>Pordis, N. J.<br>Fort Arthur, Tex.<br>Millard, Pa.<br>Eugene Island<br>(Silver Ridge),<br>Mich.<br>Chicago, Ill.<br>Cleveland, Ohio<br>Fairmont, W. Va.<br>Neville Island, Pa.<br>Monessen, Pa.<br>Coventry, R. I.<br>Groton, Conn. | -<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- |                                                                             |
| Sulfuric acid  | Fertilizer; food pre-<br>servative; copolymeri-<br>zation; upgrading of<br>drying oils; cold rub-<br>ber additive; inter-<br>mediate for plastici-<br>zers & lubricants |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                     |                                                                         |                                                                             |



Table A-1. (Continued)

| Chemical      | Use:                                                                                                                                                               | Manufacturer(s): <sup>1,2</sup>                              | Location(s): <sup>2,3</sup> | 1975 capacity: <sup>2</sup><br>MM KG (MM lb.) | Total <sup>1,5</sup> production<br>MM KG (MM lb.)<br>for year of estimate |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-----------------------------|-----------------------------------------------|---------------------------------------------------------------------------|
| Styrene       | Polystyrene plastics;<br>SRH, ABS, & SAN resins;<br>protective coatings (styrene-butadiene latex; alkyds); styrenated polymers; rubber-mastic resins; intermediate | American Petrofina, Inc. - Cuden Oil & Chem. Co., subsid.    | Big Spring, Tex.            | 54.5 (120)                                    | 2,724 (6,000) -1974                                                       |
|               |                                                                                                                                                                    | ARCO Polymers, Inc.                                          | Beaver Valley, Pa.          | 199.8 (440)                                   |                                                                           |
|               |                                                                                                                                                                    | Coca-Cola, Inc.                                              | Houston, Tex.               | 54.5 (120)                                    |                                                                           |
|               |                                                                                                                                                                    | Dow Chem. U.S.A.                                             | Carville, La.               | 272.4 (600)                                   |                                                                           |
|               |                                                                                                                                                                    | El Paso Natural Gas Co. - El Paso Co., subsid.               | Freeport, Tex.              | 749.1 (1,650)                                 |                                                                           |
|               |                                                                                                                                                                    | Foster Grant Co., Inc.                                       | Midland, Mich.              | 181.6 (400)                                   |                                                                           |
|               |                                                                                                                                                                    | Gulf Oil Corp. - Gulf Oil Chem. Co., div. - Petrochems. Div. | Odessa, Tex.                | 54.5 (120)                                    |                                                                           |
|               |                                                                                                                                                                    | Monsanto Co. - Monsanto Polymers & Petrochems. Co.           | Baton Rouge, La.            | 372.3 (820)                                   |                                                                           |
|               |                                                                                                                                                                    | Standard Oil Co. (Ind.) - Amoco Chem. Corp., subsid.         | Welcome, La.                | 227 (500)                                     |                                                                           |
|               |                                                                                                                                                                    | Sun Oil Co. - Sun Oil Co. of Penn., subsid.                  | Texas City, Tex.            | 500.2 (1,100)                                 |                                                                           |
|               |                                                                                                                                                                    | Sun Oil Refining Co., subsid.                                | Texas City, Tex.            | 385.9 (850)                                   |                                                                           |
|               |                                                                                                                                                                    | Union Carbide Corp. - Chem. & Plastics Div.                  | Corpus Christi, Tex.        | 36.3 (80)                                     |                                                                           |
|               |                                                                                                                                                                    | Allied Chem. Corp. - Specialty Chem. Div.                    | Seadrift, Tex.              | 136.2 (300)                                   |                                                                           |
|               |                                                                                                                                                                    | Richardson-Merrell, Inc. - J. T. Baker Chem. Co., subsid.    | Marcus Hook, Pa.            | Total -<br>3,314.2 (7,300)                    |                                                                           |
| Succinic acid | Medicine; organic synthesis; mfg. of lacquers, dyes, esters, perfumes, succinates; photostabilizers; in foods as sequestrant; buffer, neutralizing agent           | Phillipsburg, N. J.                                          |                             |                                               |                                                                           |
|               |                                                                                                                                                                    |                                                              |                             |                                               |                                                                           |

Table A-1. (Continued)

|                                            |                                                                                                                                                                                                                                                     |                                                                                                                                                                                             |                                                                        |                                                                |   |
|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------|---|
| Succino-<br>nitrile                        | Organic synthesis                                                                                                                                                                                                                                   | Barclay Chem. Corp. -<br>Eastern Chem. Div.<br>P.O. Corp.                                                                                                                                   | Hempstead, N. Y.<br>Ardsley, N. Y.                                     | -                                                              | - |
| Sulfo-<br>lane                             | Extraction of aromatic<br>hydrocarbons from oil;<br>refining; treatment;<br>fractionation of oil;<br>tars, tall oil & other<br>fatty acids; polymeriza-<br>tion solvent; plastic-<br>izer; component of automo-<br>bile fluid; textile<br>finishing | Phillips Petroleum Co.,<br>Refineries & Supply Div.<br>Shell Chem. Co. -<br>Base Chem.                                                                                                      | Phillips, Tex.<br>Norco, La.                                           | -                                                              | - |
| Synthesis<br>gas                           | Organic synthesis; mfg.<br>of alcohols (Oxo process);<br>low-Btu fuel gas                                                                                                                                                                           | -                                                                                                                                                                                           | -                                                                      | -                                                              | - |
| Tere-<br>phthalic<br>acid                  | Production of linear,<br>crystalline polyester<br>by using filters & films<br>by using "Mylar,"<br>"Mylar," "Terlar,"<br>also used as a reagent<br>for alkali in wool; ad-<br>ditive to poultry feeds                                               | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subd. - Tenn.<br>Eastman Co., div.<br>Hercules Inc. -<br>Synthetic Dept.<br>Standard Oil Co. (Ind.) -<br>East Chem. Corp.,<br>subd. | Kingsport, Tenn.<br>Wilmington, N. C.<br>Decatur, Ala.<br>Joliet, Ill. | 1,557 (3,430) -1974                                            | - |
| Tetra-<br>chloro-<br>ethane                | Solvent; cleansing &<br>degreasing metals; paint<br>removers, varnishes, lac-<br>quers, photographic<br>films; resins & waxes;<br>ester; solvent for oils &<br>fats; alcohol denaturant;<br>insecticides; wetting<br>agent; fumigant                | Occidental Petroleum<br>Corp. - Hooker Chem.<br>Corp., subd. - Hooker<br>Chem. & Plastics<br>Corp., subd. -<br>Electrochemical &<br>Specialty Chem. Div.                                    | Taft, La.                                                              | 113.5<br>367.2 (800)<br>45.4 (100)<br>Total =<br>522.1 (1,180) | - |
| Tetra-<br>chloro-<br>phthalic<br>anhydride | Intermediate in dyes,<br>pharmaceuticals, plasti-<br>cizers, & other organic<br>materials; flame-<br>retardant in epoxy<br>resins                                                                                                                   | Monsanto Co. - Monsanto<br>Indust. Chem. Co.                                                                                                                                                | Bridgeton, N. J.                                                       | -                                                              | - |

Table A-1. (Continued)

| <u>Chemical</u>              | <u>Usage<sup>1</sup></u>                                                                                                               | <u>Manufacturer(s)<sup>2,3</sup></u>                                                                                                                                                                                                                                                                                                                          | <u>Location(s)<sup>2,3</sup></u>                                                                                                                                                                                                  | <u>1975 capacity<br/>MM kg (MM lb)</u>                           | <u>Total<sup>4</sup><br/>production<br/>MM kg (MM lb)<br/>for year of estimate</u> |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Tetrahydro-naphthalene (TEL) | Antiknock gasoline additive; certain ethylation operations                                                                             | E. I. du Pont de Nemours & Co., Inc. -<br>Organic Chemicals Dept. - Petroleum Refining Div.<br>Ethyl Corp.                                                                                                                                                                                                                                                    | Antioch, Calif.<br>Deepwater, N. J.                                                                                                                                                                                               | 184.8 (340)                                                      | 246.7 (543.4) -1968                                                                |
|                              |                                                                                                                                        | Nalco Chem. Co. -<br>Petroleum & Process Chem. Div.                                                                                                                                                                                                                                                                                                           | Baton Rouge, La.<br>Pasadena, Tex.                                                                                                                                                                                                | 158.9 (350)                                                      | -                                                                                  |
|                              |                                                                                                                                        | EPJ Industries Inc. -<br>Chem. Div. - Houston Chem. Co., div.                                                                                                                                                                                                                                                                                                 | Pasadena, Tex.                                                                                                                                                                                                                    | 18.2 (40)                                                        | -                                                                                  |
|                              |                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                               | Beaumont, Tex.                                                                                                                                                                                                                    | 45.4 (100)                                                       | -                                                                                  |
|                              | Solvent; chemical intermediate                                                                                                         | E. I. du Pont de Nemours & Co., Inc. -<br>Dyes & Chems. Div. -<br>Luna Corp.<br>Union Carbide Corp. -<br>Chems. & Plastics Div.                                                                                                                                                                                                                               | Deepwater, N. J.<br><br>Mapleton, Ill.<br><br>Institute & South Charleston, W. Va.<br><br>Houston, Tex.                                                                                                                           | -<br><br>-<br><br>-                                              | -<br><br>-<br><br>---                                                              |
|                              | Chemical intermediate for light-colored alkyds, polyesters, plasticizers & adhesives; intermediate for pesticides; hardener for resins | Petro-Tex Chem. Corp. -<br>Petro-Tex Chem. Co., subd.                                                                                                                                                                                                                                                                                                         | Houston, Tex.                                                                                                                                                                                                                     | -                                                                | -                                                                                  |
|                              | Chemical intermediate                                                                                                                  | BASF Wyandotte Corp. -<br>Indust. Chems. Group                                                                                                                                                                                                                                                                                                                | Wyandotte, Mich.                                                                                                                                                                                                                  | -                                                                | -                                                                                  |
| Tetra-methylene-diamine      | Dye intermediate; direct oxidation black for furs & hair; source for toluene-2,4-diisocyanate                                          | Air Products & Chems., Inc.<br>American Cyanamid Co. -<br>Organic Chems. Div.<br><br>E. I. du Pont de Nemours & Co., Inc. -<br>Chem. & Plast. Dept. -<br>Dyes & Chems. Div.<br>BAC Corp. - Chem. Div.<br>Olin Corp. - Agricul-tural Chems. Div. -<br>Designed Products Div.<br><br>Rohm & Haas Co., Inc. -<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Pasadena, Tex.<br><br>Bound Brook, N. J.<br><br>Deepwater, N. J.<br><br>Rensselaer, N. Y.<br>Lake Charles, La.<br>Ashtabula, Ohio<br>Brandenburg, Ky.<br>Rochester, N. Y.<br>Geismar, La.<br>Institute & South Charleston, W. Va. | -<br><br>-<br><br>-<br><br>-<br><br>-<br><br>-<br><br>-<br><br>- | -<br><br>-<br><br>-<br><br>-<br><br>-<br><br>-<br><br>-                            |

\* Includes TEL, TML and mixtures.

Table A-1. (Continued)

| Chemical                  | Usage <sup>1</sup>                                                                                                                           | Manufacturer(s) <sup>2</sup>                                                                                                                                                                                                                                                                                           | Location(s) <sup>2,3</sup>                                                                                                               | 1975 capacity <sup>2</sup><br>MM Kk (MM lb) | Total <sup>4,5</sup><br>production<br>MM Kk (MM lb)<br>for year of estimate |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Toluene-sulfonic acids    | Dyes; organic synthesis; acid catalyst                                                                                                       | American Cyanamid Co. - Organic Chem. Div.<br>Cities Service Co., Inc. - North American Chem. & Metals Group - Indust. Chem. Div.<br>Monsanto Co. - Monsanto Indust. Chem. Co.<br>Nease Chem. Co., Inc.<br>Jim Walter Corp. - U.S. Pipe & Foundry Co., subd. - Chem. Div.<br>Monsanto Co. - Monsanto Indust. Chem. Co. | Bound Brook, N. J.<br>Copperhill, Tenn.<br>St. Louis, Mo.<br>State College, Pa.<br>Birmingham, Ala.<br>St. Louis, Mo.                    | -<br>-<br>-<br>-<br>-<br>-                  | -<br>-<br>-<br>-<br>-<br>-                                                  |
| Toluene-sulfonamide       | Organic synthesis; plasticizers & resins; fungicide & mildewicide in paints & coatings                                                       | Monsanto Co. - Monsanto Indust. Chem. Co.                                                                                                                                                                                                                                                                              | St. Louis, Mo.                                                                                                                           | -                                           | -                                                                           |
| Toluene-sulfonyl chloride | Organic synthesis; intermediate in the synthesis of saccharin & dyestuffs                                                                    | Monsanto Co. - Monsanto Indust. Chem. Co.                                                                                                                                                                                                                                                                              | St. Louis, Mo.                                                                                                                           | -                                           | -                                                                           |
| Trichlorobenzene          | Solvent in chemical wfg.; dyes & intermediates; dielectric fluid; synthetic transformer oils; lubricants; heat-transfer medium; insecticides | Dow Chem. U.S.A. Occidental Petroleum Corp. - Rocker Chem. Corp., subd. - Rocker Chem. & Plastics Corp., subd. - Electrochemical & Specialty Chem. Div.<br>Sohin Chem., Inc. - Montrose Chem. Div.<br>Solvent Chem. Co., Inc.                                                                                          | Midland, Mich.<br>Niagara Falls, N. Y.<br>Newark, N. J.<br>Malden, Mass.<br>Niagara Falls, N. Y.<br>Delaware City, Del.<br>Kearny, N. J. | -<br>-<br>-<br>-<br>-<br>-<br>-             | -<br>-<br>-<br>-<br>-<br>-<br>-                                             |
|                           |                                                                                                                                              | Standard Chlorine Chem. Co., Inc.                                                                                                                                                                                                                                                                                      |                                                                                                                                          |                                             |                                                                             |

Table A-1. (Continued)

| Chemical                         | Usage                                                                                                                                                                                                                                | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                         | Location(s)                                                            | 1975 capacity <sup>4</sup><br>MM kg (MM lb)                                 | Total <sup>5</sup> production<br>MM kg (MM lb)<br>for year of estimate |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------|
| Trichloro-<br>ethane             | Solvent for cleaning<br>precision instruments;<br>aerosol propellant;<br>metal degreasing;<br>pesticide; solvent for<br>cars, oils, waxes,<br>resins; other products;<br>organic synthesis                                           | Dow Chem. U.S.A.<br>Ethyl Corp.<br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div.<br>Vulcan Materials Co. -<br>Chem. Div.                                                                                                                                                                                                                    | Freeport, Tex.<br>Baton Rouge, La.<br>Lake Charles, La.<br>De'mar, La. | 154.4 (340)<br>22.7 (50)<br>79.4 (175)<br>29.5 (65)<br>Total =<br>286 (630) | 170.1 (374.6) -1971                                                    |
|                                  | Metal degreasing; ex-<br>traction solvent for<br>oils, fats, waxes; sol-<br>vent dyeing; dry clean-<br>ing; refrigerant &<br>heat exchange liquid;<br>organic syntheses;<br>insecticides; clean-<br>ing & drying electronic<br>parts | Diamond Shamrock Corp. -<br>Diamond Shamrock Chem.<br>Co. - Electro Chem.<br>Div.<br>Dow Chem. U.S.A.<br>Ethyl Corp.<br>Occidental Petroleum<br>Corp. - Hooker Chem. Corp. -<br>subsidi. - Hooker Chem.<br>& Plastics Corp. -<br>subsidi. - Electrochemi-<br>cal & Specialty Chem.<br>Div.<br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div. | Deer Park, Tex.<br>Freeport, Tex.<br>Baton Rouge, La.<br>Tat, La.      | 85.4 (100)<br>68.1 (150)<br>22.7 (50)<br>18.2 (40)                          | -                                                                      |
|                                  | Paint & varnish remover;<br>solvent; degreasing agent                                                                                                                                                                                | Dow Chem. U.S.A.<br>Shell Chem. Co. -<br>Base Chem.                                                                                                                                                                                                                                                                                                     | Freeport, Tex.<br>Deer Park, Tex.                                      | Total =<br>281.5 (620)                                                      | -                                                                      |
| 1,2,3-Tri-<br>chloro-<br>propane |                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                         |                                                                        |                                                                             |                                                                        |

Table A-1. (Continued)

| Chemical              | Usage:                                                                                                                                                                                                                                                                                     | Manufacturer(s)                                                                                                                                 | Location(s)                                                                                                         | 1975 capacity?<br>MM KG (MM lb.)           | Total<br>production<br>MM KG (MM lb.)<br>for year of estimate |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---------------------------------------------------------------|
| 1,1,2-Trichloroethane | Dry cleaning solvent; fire extinguishers; refrigerant; air-conditioning units; to make chlorotrifluoroethylene; blowing agent; polymer intermediate; solvent drying; drying electronic parts & precision equipment                                                                         | Allied Chem. Corp. - Specialty Chem. Div.<br>E. I. du Pont de Nemours & Co. - Chlorofluorocarbon Div.<br>Frederick Products, Inc.               | Baton Rouge, La.<br>Antioch, Calif.<br>Des Moines, Iowa<br>East Chicago, Ind.<br>Louisville, Ky.<br>Montague, Mich. | -<br>-<br>-<br>-<br>-                      | -                                                             |
| Tri-ethanol amine     | Fatty acid soaps used in drycleaning, cosmetics, household detergents, emulsifiers, wetting agents, scouring, textile antifume agent & water-repellent; dispersion agent; corrosion inhibitor; softening agent; humectant, & plasticizer; insecticide; chelating agent; rubber accelerator | Union Carbide Corp. - Chem. & Plastics Div.<br>(See diethanolamine)                                                                             | Institute & South Charleston, W. Va.<br>-                                                                           | -<br>-                                     | 30 (100) -1974                                                |
| Triethylamine         | Catalytic solvent in chemical synthesis; accelerator activators for rubber; setting, penetrating, & degreasing agents; bacteriary ammonium types; curing & hardening of polymers (e.g., core-binding resins); corrosion inhibitor; propellant                                              | Air Products & Chem. Inc.<br>Pennwalt Corp. - Chem. Div.<br>Union Carbide Corp. - Chem. & Plastics Div.<br>Va. Chem. Ind. - Indust. Chem. Dept. | Pensacola, Fla.<br>Wyandotte, Mich.<br>Taft, La.<br>Portsmouth, Va.                                                 | -<br>-<br>-<br>-                           | -                                                             |
| Tri-ethylene glycol   | Solvent for nitrocellulose; various gums & resins; lacquers; organic synthetics; air-conditioning units; bactericide (in vapor form); humectant; textile printing ink; textile conditioner; fungicide                                                                                      | Allied Chem. Corp. - Specialty Chem. Div.<br>Celanese Corp. - Celanese Chem. Co., Div.<br>Dixie Chem. Co.<br>Iowa Chem. Ind. Co.                | Orange, Tex.<br>Clear Lake, Tex.<br>Bayport, Tex.<br>Freeport, Tex.<br>Piquemine, La.                               | 1.4 (3)<br>1.4 (3)<br>0.9 (2)<br>15.9 (35) | 51.3 (113.1) -1973                                            |

Table A-1. (Continued)

| Chemical                                        | Use:                                                                                                                                                                                                                   | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                       | Location(s)                                                                                                                                                                                                     | 1975<br>capacity,<br>MM kg (MM lb)                                                     | Total<br>production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Tri-<br>ethylene<br>glycol<br>(cont'd)          | (See previous page)                                                                                                                                                                                                    | Eastman Kodak Co. -<br>Eastman Chem. Products,<br>Inc., subd., - Texas<br>Eastman Co., div.<br>Olin Corp. - Designed<br>Products Div.<br>PPG Indust., Inc. -<br>Chem. Div. - Houston<br>Chem. Co., div. -<br>PPG Indust. (Carbide)<br>Shell Chem. Co. -<br>Base Chem.<br>Texaco Inc. - Jefferson<br>Chem. Co., Int., subd.<br>Union Carbide Corp. -<br>Chem. & Plastics Div.<br>Union Carbide Carbide,<br>Inc., subd. | Longview, Tex.<br><br>Brandenburg, Ky.<br>Beaumont, Tex.<br>Guyanilla, P. R.<br>Geismar, La.<br>Port Neches, Tex.<br>Institute & South<br>Charleston, W. Va.<br>Geodrift, Tex.<br>Patt, La.<br>Pensacola, P. R. | <0.5 (<1)<br><br><0.5 (<1)<br><0.5 (<1)<br><0.5 (<1)<br>1.8 (4)<br>4.5 (10)<br>34 (75) | (See previous page)                                          |
| Tri-<br>ethylene<br>glycol<br>dimethyl<br>ether | Solvent for gases;<br>coupling immiscible<br>liquids                                                                                                                                                                   | The Ansul Co. -<br>Chem. Div.                                                                                                                                                                                                                                                                                                                                                                                         | Marquette, Wisc.                                                                                                                                                                                                | Total =<br><61.7 (<136)                                                                | -                                                            |
| Tri-<br>ethyl-<br>amine                         | Organic synthesis, es-<br>pecially of chlorine salts;<br>warning agent for natu-<br>ral gas; manufacture of<br>disinfectants; photo-<br>sensitive; insect<br>attractant; quaternary<br>ammonium compounds;<br>plastics | Air Products & Chem.,<br>Inc.<br>Commercial Solvents Corp.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Biomass Dept.<br>OAF Corp. - Chem. Div.<br>Rohm & Haas Co.                                                                                                                                                                                                                                               | Pensacola, Fla.<br>Terre Haute, Ind.<br>Belle, W. Va.<br>La Porte, Tex.<br>Calvert City, Ky.<br>Philadelphia, Pa.                                                                                               | -<br>-<br>-<br>-<br>-<br>-                                                             | 13.1 (28.9) -1973                                            |

Table A-1. (Continued)

| Chemical                 | Usage <sup>1</sup>                                                                                                                                                                                                                                                                                                                                                    | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Location(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                         | 1975 capacity <sup>2</sup><br>MM KG (MM lb)                                                                                                                                                                                                                                          | Total <sup>4,5</sup><br>production<br>MM KG (MM lb)<br>for year of estimate |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Tri-<br>isobuty-<br>lene | Synthesis of resins, &<br>intermediate organic<br>compounds; lubricating<br>oil additive, raw<br>material for alkyl-<br>ation in producing<br>high octane motor fuels                                                                                                                                                                                                 | The B. F. Goodrich<br>Co. - B. F. Goodrich<br>Chem. Co., div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Port Neches, Tex.                                                                                                                                                                                                                                                                                                                                                  | -                                                                                                                                                                                                                                                                                    | -                                                                           |
| Urea                     | Fertilizer; animal feed;<br>plastics; chemical inter-<br>mediate; stabilizer in<br>explosives; medicine;<br>adhesives; separation of<br>hydrocarbons (as urea<br>adducts); sulfamic<br>acid production; flame-<br>proofing agents; vis-<br>cosity modifier for<br>starch or casein-based<br>paper coatings; re-<br>ported helpful in treat-<br>ing sickle-cell anemia | Agway Inc.<br>Air Products & Chem-<br>icals, Inc.<br>Allied Chem. Corp. -<br>Specialty Chems. Div. -<br>Union Texas Petroleum<br>Div. - Agricultural Div.<br>American Cyanamid Co. -<br>Agricultural Div.<br>Borden Inc. - Borden<br>Chem. Div. - Petrochems.<br>CF Indust., Inc. -<br>Chattanooga Nitrogen<br>Complex - Donaldsonville<br>Nitrogen Complex -<br>Fremont Nitrogen Complex<br>N. C. Nitrogen Complex<br>Coastal States Gas<br>Corp. - Colorado Inter-<br>state Corp., subsid. -<br>Wyon Chem. Co., subsid.<br>Columbia Nitrogen Corp.<br>Cooperative Farm Chem-<br>ical Association<br>Gardiner Big River, Inc.<br>Gen. Amer. Oil of Tex. -<br>Premier Petrochem. Co.,<br>subsid.<br>W. R. Grace & Co. -<br>Agricultural Chems. Group<br>Hercules Inc. - Synthe-<br>tics Dept. | Olean, N. Y.<br>Pensacola, Fla.<br>South Point, Ohio<br>Geismar, La.<br>Omaha, Neb.<br>New Orleans, La.<br>Geismar, La.<br>Tynes, Tenn.<br>Donaldsonville,<br>La.<br>Fremont, Neb.<br>Tunis, N. C.<br>Cheyenne, Wyo.<br>Augusta, Ga.<br>Lawrence, Kans.<br>Helena, Ark.<br>Pasadena, Tex.<br>Dimmitt, Tex.<br>Memphis, Tenn.<br>Hercules, Calif.<br>Louisiana, Mo. | 54.5 (120)<br>22.7 (50)<br>63.6 (140)<br>304.3 (663)<br>127.1 (280)<br>131.7 (290)<br>177.1 (390)<br>36.3 (80)<br>331.2 (730)<br>18.2 (40)<br>154.4 (340)<br>45.4 (100)<br>27.2 (60)<br>181.6 (400)<br>59 (130)<br>95.3 (210)<br>22.7 (50)<br>122.6 (270)<br>36.3 (80)<br>86.3 (190) | 3,350 (7,380)-1974                                                          |



Table A-1. (Continued)

| Chemical         | Usage               | Manufacturer(s)                                                   | Location(s)                     | 1975 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>1,5</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|------------------|---------------------|-------------------------------------------------------------------|---------------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
| Urea<br>(cont'd) | (See previous page) |                                                                   |                                 |                                             | (See previous page)                                                         |
|                  |                     | Kaiser Aluminum & Chem. Corp. - Kaiser Agricultural Chems. Div.   | Savannah, Ga.                   | 72.6 (160)                                  |                                                                             |
|                  |                     | Lone Star Gas Co. - Nipak, Inc., subd.                            | Kerens, Tex.<br>Fryer, Okla.    | 77.2 (170)<br>122.6 (270)                   |                                                                             |
|                  |                     | Miss. Chem. Corp.                                                 | Yazoo City, Miss.               | 168 (370)                                   |                                                                             |
|                  |                     | Mobil Oil Corp. - Mobil Chem. Co., div. - Petrochems. Div.        | Beaumont, Tex.                  | 45.4 (100)                                  |                                                                             |
|                  |                     | N-Ren Corp. - Cherokee Nitrogen Div. - High Plains Div.           | Pryor, Okla.<br>Flattinew, Tex. | 18.2 (40)<br>54.5 (120)                     |                                                                             |
|                  |                     | Olin Corp. - Agricultural Chems. Div.                             | Lake Charles, La.               | 145.3 (320)                                 |                                                                             |
|                  |                     | Phillips Pacific Chem. Co.                                        | Kennelick, Wash.                | 40.9 (90)                                   |                                                                             |
|                  |                     | Phillips Petroleum Co. - Fertilizer Div.                          | Beatrice, Neb.                  | 50 (110)                                    |                                                                             |
|                  |                     | Reichhold Chems., Inc.                                            | St. Helens, Ore.                | 50 (110)                                    |                                                                             |
|                  |                     | St. Paul Ammonia Products, Inc.                                   | East Dubuque, Ill.              | 72.6 (160)                                  |                                                                             |
|                  |                     | J. R. Simplot Co. - Minerals & Chem. Div.                         | Pocatello, Idaho                | -                                           |                                                                             |
|                  |                     | Skelly Oil Co. - Hawkeye Chem. Co., subd.                         | Clinton, Iowa                   | 54.5 (120)                                  |                                                                             |
|                  |                     | The Standard Oil Co. (Ohio) - Vistron Corp., subd. - Chems. Dept. | Lima, Ohio                      | 217.9 (480)                                 |                                                                             |
|                  |                     | Tenn. Valley Authority                                            | Muscle Shoals, Ala.             | 63.6 (140)                                  |                                                                             |
|                  |                     | Terra Chems. Internat'l, Inc.                                     | Fort Neal, Iowa                 | 154.4 (340)                                 |                                                                             |
|                  |                     | Triad Chem.                                                       | Donaldsonville, La.             | 449.5 (970)                                 |                                                                             |

Table A-1. (Continued)

| Chemical         | Usage <sup>1</sup><br>(See previous page)                                                                                                                                                                                                                    | Manufacturer(s) <sup>2,3</sup>                                                                                                                                                                                                                                                                                                                                                                                                 | Location(s) <sup>2,3</sup>                                                                                                                                          | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb)                                                                              | Total <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Urea<br>(con'd)  |                                                                                                                                                                                                                                                              | Tyler Corp. - Atlas<br>Powder Co., subsid.<br>Union Oil Co. of Calif.<br>Collifer Carbon & Chem.<br>Corp., subsid.<br>U.S. Steel Corp. -<br>USS Agri-Chem. div.<br>Valley Nitrogen Pro-<br>ducers, Inc.<br>The Williams Companies -<br>Agrico Chem. Co.,<br>subsid.                                                                                                                                                            | Joplin, Mo.<br>Brea, Calif.<br>Kenai, Alaska<br>Cherokee, Ala.<br>El Centro, Calif.<br>Heim, Calif.<br>Blytheville, Ark.<br>Donaldsonville, La.                     | 50 (135)<br>50 (110)<br>308.7 (680)<br>22.7 (50)<br>140.7 (310)<br>31.8 (70)<br>299.6 (660)<br>299.6 (660)                  |                                                                                                    |
|                  |                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                     | Total =<br>5,057.6 (11,140)                                                                                                 |                                                                                                    |
| Vinyl<br>acetate | Polyvinyl acetate, poly-<br>vinyl alcohol, poly-<br>vinyl butyral & poly-<br>vinyl chloride-acetate<br>resins (q.v.); these are<br>used particularly in<br>latex paints; paper<br>coating; adhesives;<br>textile finishing;<br>safety glass inter-<br>layers | Borden Inc. - Borden<br>Chem. Div. - Petrochems.<br>Celanese Corp. - Cels-<br>nese Chem. Co., div.<br>E. I. du Pont de Ne-<br>mours & Co., Inc. -<br>Plastics Dept.<br>National Distillers &<br>Chem. Corp. - Chem.<br>Div. - U.S. Indust.<br>Chem. Co., div.<br>National Starch & Chem.<br>Corp.<br>Reichhold Chem., Inc. -<br>Reichhold Chem. Del<br>Caribe, Inc., subsid.<br>Union Carbide Corp. -<br>Chem. & Plastics Div. | Geismar, La.<br>Bay City, Tex.<br>Clear Lake, Tex.<br>Pampa, Tex.<br>La Porte, Tex.<br>Deer Park, Tex.<br>Long Mott, Tex.<br>Rio Piedras, P. R.<br>Texas City, Tex. | 89.1 (195)<br>136.2 (300)<br>159.3 (350)<br>29.5 (65)<br>158.9 (350)<br>170.2 (375)<br>31.8 (70)<br>6.8 (15)<br>120.3 (265) | 635.6 (1,400) -1974                                                                                |
|                  |                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                     | Total =<br>936.8 (1,940)                                                                                                    |                                                                                                    |

Table A-1. (Continued)

| Chemical          | Use:                                                                                       | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Location(s)                                                                                                                                                                                                                                                                                                                  | 1975<br>Capacity, <sup>2</sup><br>MM kg (MM lb)                                                                                                                                                                                                 | Totals<br>Production<br>MM kg (MM lb)<br>for year of estimate |
|-------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Vinyl<br>chloride | Polyvinyl chloride (d.v.)<br>& copolymers; organic<br>synthesis; adhesives<br>for plastics | Allied Chem. Corp. -<br>Indust. Chems. Div.<br>Borden Inc. - Borden<br>Chem. Div. - Petrochems.<br>Continental Oil Co. -<br>Conoco Chems.<br>Dow Chem. U.S.A.<br><br>Ethyl Corp.<br><br>The E. F. Goodrich Co. -<br>R. F. Goodrich Chem.,<br>Co., subsid.<br>Monochem, Inc.<br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div. - PPG Indust.<br>(Caribe)<br>Shell Chem. Co. - Base<br>Chems.<br>Stauffer Chem. Co. -<br>Plastics Div. - Poly-<br>mers West<br>Tenneco Inc. - Tenneco<br>Chems., Inc. - Organics<br>& Polymers Div.<br>Union Carbide Corp. -<br>Chems. & Plastics Div. | Baton Rouge, La.<br>Geismar, La.<br>Westlake, La.<br>Freeport, Tex.<br>Oyster Creek, Tex.<br>Plaquemine, La.<br>Baton Rouge, La.<br>Pasadena, Tex.<br>Calvert City, Ky.<br><br>Geismar, La.<br>Lake Charles, La.<br>Guaynilla, P. R.<br>Deer Park, Tex.<br>Norco, La.<br>Carson, Calif.<br>Houston, Tex.<br>Texas City, Tex. | 136.2 (300)<br>-<br>295.1 (650)<br>90.8 (200)<br>317.8 (700)<br>177.1 (390)<br>136.2 (300)<br>68.1 (150)<br>454 (1,000)<br><br>136.2 (300)<br>181.6 (400)<br>227 (500)<br>381.4 (840)<br>317.8 (700)<br>79.5 (175)<br>132.1 (225)<br>68.1 (150) | 2,542 (5,600) -1974<br>Total =<br>3,160 (6,080)               |

Table A-1. (Continued)

| Material                  | Use(s)                                                                                                                                                                  | Manufacturer(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Location(s)                                                                                                                                               | 1975 capacity <sup>2</sup><br>MM kg (MM lb)                                                             | Total <sup>1,2,3</sup><br>production<br>MM kg (MM lb)<br>for year of estimate |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Vinyl-<br>ene<br>chloride | Copolymerized with vinyl<br>chloride or acryloni-<br>trile to form various<br>kinds of resin; other<br>specimens also made;<br>used as component of<br>synthetic fibers | Dow Chem. U.S.A.<br><br>PPG Indust., Inc. -<br>Chem. Div. - Indust.<br>Chem. Div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Freeport, Tex.<br>Pasadena, La.<br>Lake Charles, La.                                                                                                      | -<br>-<br>-                                                                                             | 77.2 (170) -1974                                                              |
| Vinyl<br>toluene          | Solvent; intermediate                                                                                                                                                   | Dow Chem. U.S.A.<br>Postor Grant Co., Inc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Midland, Mich.<br>Eaton Rouge, La.                                                                                                                        | -<br>-                                                                                                  | -                                                                             |
| m-xylene                  | Solvent; intermediate for<br>dyes & organic synthesis;<br>solid isophthalic<br>acid; insecticides;<br>aviation fuel                                                     | Atlantic Richfield<br>Co. - ARCO Chem. Co.,<br>div.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Channelview, Tex.                                                                                                                                         | 15.9 (35)                                                                                               | 35.4 (78) -1970                                                               |
| o-xylene                  | Mfg. of phthalic an-<br>hydride; vitamin E<br>pharmaceutical synthesis;<br>dyes; insecticides; motor<br>fuels                                                           | American Petrofina,<br>Inc. - Cosden Oil &<br>Chem. Co., subsid.<br>Atlantic Richfield Co. -<br>ARCO Chem. Co., div.<br>Cities Service Co.,<br>Inc. - North American<br>Petroleum Group<br>Coastal States Gas<br>Corp. - Coastal States<br>Marketing, Inc., subsid.<br>Commonwealth Oil Refin-<br>ing Co., Inc. - Commu-<br>wealth Petrochems.,<br>Inc., subsid.<br>Crown Central Petroleum<br>Corp.<br>Exxon Corp. - Exxon<br>Chem. Co., div.<br>Exxon Chem. Co. U.S.A.<br>Kerr-McCormick Corp. - South-<br>western Refining Co.,<br>Inc., subsid. | Big Spring, Tex.<br><br>Houston, Tex.<br>Lake Charles, La.<br>Corpus Christi,<br>Fannin, P. R.<br>Pasadena, Tex.<br>Baytown, Tex.<br>Corpus Christi, Tex. | 8.2 (18)<br>95.3 (210)<br>54.5 (120)<br>18.2 (40)<br>63.6 (140)<br>34 (75)<br>222.5 (490)<br>45.4 (100) | 374.4 (824.8) -1970                                                           |

Table A-1. (Continued)

| Chemical             | Usage <sup>1</sup>                                                                                                                             | Manufacturer(s) <sup>2,3</sup>                                                                                   | Location(s) <sup>2,3</sup> | 1976 capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>1,2</sup> production<br>MM kg (MM lb)<br>for year of estimate |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------------------|--------------------------------------------------------------------------|
| o-xylene<br>(cont'd) | (See previous page)                                                                                                                            | Monsanto Co. - Monsanto Polymers & Petrochemicals.                                                               | Chocolate Bayou, Tex.      | 13.6 (30)                                   | (See previous page)                                                      |
|                      |                                                                                                                                                | Phillips Petroleum Co. - Phillips Puerto Rico Core, Inc., subsid.                                                | Guayama, P. R.             | 50 (110)                                    |                                                                          |
|                      |                                                                                                                                                | Shell Chem. Co. - Base Chem.                                                                                     | Deer Park, Tex.            | 90.8 (200)                                  |                                                                          |
|                      |                                                                                                                                                | Standard Oil Co. of Calif. - Chevron Chem. Co., subsid. - Oronite Additives & Indust. Chem. Div. - Indust. Chem. | Richmond, Calif.           | 67.2 (148)                                  |                                                                          |
|                      |                                                                                                                                                | Sun Oil Co. - Sun Oil Co. of Penn., subsid. - Surtide Refining Co., subsid.                                      | Corpus Christi, Tex.       | 72.6 (160)                                  |                                                                          |
|                      |                                                                                                                                                | Tenneco Inc. - Tenneco Oil Co., div.                                                                             | Chalmette, La.             | 70.4 (155)                                  |                                                                          |
|                      |                                                                                                                                                |                                                                                                                  |                            | Total = 915.3 (2,016)                       |                                                                          |
|                      |                                                                                                                                                | Atlantic Richfield Co. - ARCO Chem. Co., div.                                                                    | Houston, Tex.              | 181.6 (400)                                 | 1,216.7 (2,680) -1974                                                    |
|                      |                                                                                                                                                | The Charter Co. - Charter Oil Co., subsid. Charter Internat'l Co., subsid.                                       | Houston, Tex.              | 6.8 (15)                                    |                                                                          |
|                      |                                                                                                                                                | Cities Service Co., Inc. - North American Petroleum Group                                                        | Lake Charles, La.          | 15.9 (35)                                   |                                                                          |
| p-xylene             | Synthesis of terephthalic acid for polyester resins & fibers ("Dacron," "Mylar," "terylene"); vitamin & pharmaceutical syntheses; insecticides | Exxon Corp. - Exxon Chem. Co., div. - Exxon Chem. Co. U.S.A.                                                     | Baytown, Tex.              | 181.6 (400)                                 |                                                                          |
|                      |                                                                                                                                                | Herco Chem. Corp.                                                                                                | Penueles, P. R.            | 236.3 (525)                                 |                                                                          |
|                      |                                                                                                                                                | Phillips Petroleum Co. - Phillips Puerto Rico Core Inc., subsid.                                                 | Guayama, P. R.             | 34 (75)                                     |                                                                          |
|                      |                                                                                                                                                |                                                                                                                  |                            |                                             |                                                                          |

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Table A-1. (Continued)

| Chemical                                            | Usage <sup>1</sup><br>(See previous page)                                                                                                                                                                                                                  | Manufacturer(s) <sup>2,3</sup>                                                                                                | Location(s) <sup>2,3</sup>                                            | 1975<br>capacity <sup>2</sup><br>MM kg (MM lb) | Total <sup>4,5</sup><br>Production<br>MM kg (MM lb)<br>for year of estimate<br>(See previous page) |
|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------|
| p-Xylene<br>(cont'd)                                |                                                                                                                                                                                                                                                            |                                                                                                                               |                                                                       |                                                |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            | Shell Chem. Co. -<br>Base Chem.                                                                                               | Deer Park, Tex.                                                       | 45.4 (100)                                     |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            | Standard Oil Co. of<br>Calif. - Chevron Chem.<br>Co., subd. - Cronite<br>Additives & Indust.<br>Chem. Div. - Indust.<br>Chem. | El Segundo, Calif.<br>Pascagoula, Miss.<br>Richmond, Calif.           | 140.7 (310)<br>50 (110)                        |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            | Standard Oil Co. (Ind.) -<br>Amoco Chem. Corp.,<br>subd.                                                                      | Decatur, Ala.<br>Texas City, Tex.                                     | 124.8 (275)<br>124.8 (275)                     |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            | Sun Oil Co. - Sun Oil<br>Co. of Penn., subd.<br>Sunbelt Refining Co.,<br>subd.                                                | Corpus Christi,<br>Calif.                                             | 136.2 (300)                                    |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            | Tenneco Int. - Tenneco<br>Oil Co., div.                                                                                       | Chalmette, La.                                                        | 45.4 (100)                                     |                                                                                                    |
|                                                     |                                                                                                                                                                                                                                                            |                                                                                                                               | Total =                                                               | 1,325.7 (2,920)                                |                                                                                                    |
| Xylenol<br>(mixed 2,<br>4-; 2,5-;<br>3,4-;<br>3,5-) | Disinfectants; solvents;<br>pharmaceuticals; insect-<br>icides & fungicides;<br>plasticizers; rubber<br>chemicals; additives to<br>lubricants & gasoline;<br>manufacture of poly-<br>phenylene oxide<br>(2,6-isomer only);<br>wetting agents;<br>dyestuffs | Koppers Co., Inc. -<br>Organic Materials Div.<br>Productol Chem. Co.<br>Stimson Lumber Co. -                                  | Pollansbee, W. Va.<br>Santa Fe Springs,<br>Calif.<br>Anacortes, Wash. | -<br>-<br>-                                    | -                                                                                                  |
| Xylidine<br>(mixed 2,3-;<br>2,4-; 2,5-;<br>2,6-)    | Dye intermediates;<br>organic syntheses;<br>pharmaceuticals                                                                                                                                                                                                | E. I. du Pont de Ne-<br>mours & Co., Ind.<br>Organic Chem. Dept. -<br>Dyes & Chem. Div.                                       | Deepwater, N. J.                                                      | -                                              | -                                                                                                  |

APPENDIX B

RAW MATERIALS

Table B-1. RAW MATERIALS FOR THE  
INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

|                                     |                            |                                              |
|-------------------------------------|----------------------------|----------------------------------------------|
| *Acetaldehyde                       | *Benzaldehyde              | Carbon dioxide                               |
| *Acetaldo1                          | *Benzene                   | Carbon monoxide                              |
| *Acetanilide                        | *m-Benzene disulfonic acid | *Carbon disulfide                            |
| *Acetic acid                        | *p-Benzene disulfonic acid | *Carbon tetrachloride                        |
| *Acetic anhydride                   | *Benzene sulfonic acid     | Catalytic gas oils                           |
| *Acetone                            | *Benzil                    | $\alpha$ -Cellulose                          |
| *Acetone cyanohydrin                | *Benzoic acid              | Charcoal                                     |
| *Acetonitrile                       | *Benzoin                   | Chlorine (dry)                               |
| Acetyl chloride                     | *p-Benzoquinone            | *Chloracetic acid                            |
| *Acetylene                          | *Benzotrichloride          | *Chlorobenzene                               |
| *Acrolein                           | *Benzoyl chloride          | *Chloroform                                  |
| *Acrylic acid                       | *Benzyl chloride           | *Chlorotoluene                               |
| *Acrylonitrile                      | Bromine                    | Coal tars                                    |
| Air                                 | *Bromobenzene              | Cobalt toluate                               |
| Alkyl amines                        | *1,3-Butadiene             | *Crotonaldehyde                              |
| Alkyl benzenes                      | *n-Butane                  | *Cumene                                      |
| Alkyl chlorides                     | 2-Butanone                 | *Cumene hydroperoxide                        |
| *Allyl alcohols                     | *1-Butene                  | *Cyanogen chloride                           |
| *Allyl chlorides                    | *2-Butene                  | *Cyclohexane                                 |
| Alumina gel                         | *n-Butenes                 | *Cyclohexanol                                |
| Aluminum chloride                   | *n-Butyraldehyde           | *Cyclohexanone                               |
| Ammonia                             | *n-Butyl alcohol           |                                              |
| Ammonium salts<br>(e.g., carbonate) | *sec-Butyl alcohol         | *Diacetone alcohol                           |
| *Amyl alcohols                      | *tert-Butyl alcohol        | Diallyl ether - group name                   |
| *Amyl chlorides                     | *tert-Butyl toluene        | *o-Dichlorobenzene                           |
| *Aniline                            | *Butyric acid              | *m-Dichlorobenzene                           |
| *Aniline hydrochloride              | Calcium carbonate          | *Dichlorohydrin                              |
| Aniline sulfate                     | Calcium hydroxide          | *Diethylene glycol dibutyl ether             |
| Antimony (III) fluoride             | Calcium oxide              | Diethylene glycol monoethers - group<br>name |
| Aromatics, C <sub>8</sub> -groups   | Carbon                     | *Diethyl ether                               |



Table B-1 (Continued). RAW MATERIALS FOR THE  
INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

|                        |                    |                                               |
|------------------------|--------------------|-----------------------------------------------|
| Diethyl oxalate        | Flue gas           | *Isopropyl chloride                           |
| *1,1-Difluoroethane    | *Formaldehyde      |                                               |
| *Diisobutylene         | *Formic acid       | *Ketene                                       |
| Dimethyl acetal        | *Fumaric acid      |                                               |
| *Dimethyl sulfate      | Furfural           | Lead                                          |
| *Dimethyl sulfide      |                    | Lead amalgam                                  |
| *Dinitrobenzenes       | *Glyceraldehyde    | Light cycle oils                              |
| *Dinitrobenzoic acid   | *Glycerol          |                                               |
| *Dinitrotoluene        |                    | *Maleic acid                                  |
| *Diphenyl oxide        | *Heptene           | *Maleic anhydride                             |
| *Dodecene              | Hexyl alcohol      | Manganese dioxide                             |
| Drip oils              | Hydrochloric acid  | *Mesityl oxide                                |
|                        | Hydrofluoric acid  | *Methallyl chloride                           |
| *Epichlorohydrin       | Hydrogen           | Methane                                       |
| *Ethane                | Hydrogen bromide   | *Methyl acetate                               |
| *Ether                 | Hydrogen chloride  | *Methyl alcohol                               |
| *Ethyl acetate         | *Hydrogen cyanide  | *Methyl chloride                              |
| *Ethyl alcohol         | Hydrogen fluoride  | *Methyl cyclohexane                           |
| *Ethyl benzene         | Hydrogen peroxide  | *Methyl ethyl ketone                          |
| *Ethyl chloroacetate   | *Hydroquinone      | *Methyl formate                               |
| *Ethyl chloride        | Hypochlorous acid  | Methyl iodide                                 |
| Ethyl formate          |                    | *Methyl isobutyl ketone                       |
| Ethyl sulfate          | Iron sulfate       | Methyl propene                                |
| Ethyl toluene          | *Isamylenes        | *Methylene chloride                           |
| Ethylene               | Isobutane          | Monoethylene glycol monoether -<br>group name |
| *Ethylene chlorohydrin | Isobutene          |                                               |
| *Ethylene diamine      | *Isobutyl alcohol  | *Naphthalene                                  |
| *Ethylene dibromide    | Isobutylene        | *1-Naphthalene sulfonic acid                  |
| *Ethylene dichloride   | *Isobutyraldehyde  | *2-Naphthalene sulfonic acid                  |
| *Ethylene glycol       | Isopentane         | Natural gas                                   |
| *Ethylene oxide        | *Isopropyl alcohol | Nitric acid                                   |

Table B-1 (Continued). RAW MATERIALS FOR THE  
INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

|                                             |                                 |                             |
|---------------------------------------------|---------------------------------|-----------------------------|
| *Nitrobenzene                               | Potassium sulfide               | *Sodium phenate             |
| m-Nitrochlorobenzene                        | *Propane, liquid                | Sodium "salt"               |
| Nitrogen                                    | *n-Propyl alcohol               | Sodium stearate             |
| Nitrogen dioxide<br>(dinitrogen tetraoxide) | *n-Propyl chloride              | Sodium sulfide              |
| *o-Nitroanisole                             | Propylene                       | Sodium sulfite              |
| *p-Nitroanisole                             | *Propylene chlorohydrin         | Sulfur, organic derivatives |
| *o-Nitrophenol                              | Propylene glycol                | Sulfur dioxide              |
| *p-Nitrophenol                              | *Propylene oxide                | Sulfur dioxide, liquid      |
| Nitrosylsulfuric acid                       | *Pyridine                       | Sulfur trioxide             |
| *Nitrotoluene                               | Refinery gas caustic<br>extract | Sulfuric acid               |
| *Nonene                                     | Reformer bottoms                | Oleum                       |
| Octyl alcohol                               |                                 | Sulfuric acid, monohydrate  |
| "Olefins"                                   | Silica gel                      | Synthesis gas               |
| Oxalic acid (dihydrate)                     | Sodium                          | *1,1,2,2-Tetrachloroethane  |
| Oxygen                                      | *Sodium acetate                 | Tetrahydrofuran             |
| *Pentane                                    | Sodium bicarbonate              | *Trichloroaniline           |
| Peracetic acid                              | Sodium bisulfite                | *1,1,2-Trichloroethane      |
| *Perchloroethylene                          | Sodium carbonate                | *Trichloroethylene          |
| *Phenol                                     | Sodium carbonate<br>emulsifier  | 2,4,6-Trichlorophenol       |
| *Phosgene                                   | *Sodium chloroacetate           | Toluene                     |
| Phosphorous tribromide                      | Sodium chloride                 | *Toluene sulfonyl chloride  |
| *Phthalic anhydride                         | Sodium cyanide                  | *Toluidine                  |
| *Phthalimide                                | Sodium dichromate               | Tolunitrile                 |
| Polychloroaromatics                         | Sodium ethoxide                 |                             |
| Potassium t-butoxide                        | *Sodium formate                 | *Urea                       |
| Potassium cyanide                           | Sodium hydrosulfide             | Water                       |
| Potassium hydrosulfide                      | Sodium hydrosulfite             | Water, demineralized        |
| Potassium hydroxide                         | Sodium hydroxide                | Water, distilled            |
| Potassium permanganate                      | Sodium perborate                | Water, steam                |

Table B-1 (Continued). RAW MATERIALS FOR THE  
INDUSTRIAL ORGANIC CHEMICALS INDUSTRY

\*m-Xylene

\*o-Xylene

\*p-Xylene

Zeolite, synthetic

Zinc

---

\* Indicates chemical is also a product of this industry.

Table C-1. CATALYSTS USED IN THE PRODUCTION  
OF INDUSTRIAL ORGANIC CHEMICALS

|                                                            |                                                                      |
|------------------------------------------------------------|----------------------------------------------------------------------|
| Acetic acid                                                | Carbon, activated                                                    |
| Alkali metals                                              | Carboxyl salts of divalent transition metals, e.g., zinc isovalerate |
| Alumina                                                    | Chromic acid                                                         |
| Alumina, modified anhydrous Gamma                          | Cobalt acetate                                                       |
| Alumina, gel                                               | Cobalt carbonyl compounds                                            |
| Alumina-chromia                                            | Cobalt carbonyl compounds, phosphorus promoted                       |
| Aluminum turnings                                          | Cobalt compounds                                                     |
| Aluminum alkoxides                                         | Cobalt-manganese activated by bromine                                |
| Aluminum chloride                                          | Cobalt-manganese activated by acetaldehyde                           |
| Amine bases                                                | Cobalt-manganese activated by methyl ethyl ketone                    |
| Ammonium chloride                                          | Cobalt naphthenate                                                   |
| Ammonium metavanadate                                      | Cobalt oxides                                                        |
| Ammonium persulfate-ammonium bromide                       | Cobalt "salts"                                                       |
| Aniline hydrochloride                                      | Cobalt "salts" activated by bromine                                  |
| Antimony, partially fluorinated                            | Cobalt stearate                                                      |
| Antimony (III) chloride                                    | Copper                                                               |
| Antimony (V) chloride                                      | Copper, solid, promoted by cobalt or chromium on asbestos            |
| Antimony (V) fluoride                                      | Copper-silica                                                        |
| Barium chloride on carbon                                  | Copper acetate                                                       |
| Barium hydroxide                                           | Copper chromite                                                      |
| Bauxite                                                    | Cuprammonium nitrate                                                 |
| Bismuth-molybdenum                                         | Cupric chloride                                                      |
| Boric acid                                                 | Cupric chloride impregnated on a fluid - or fixed-bed support        |
| Boron trifluoride                                          | Cupric oxide                                                         |
| Brass                                                      | Cupric sulfate                                                       |
| Bromine                                                    | Cuprous oxide                                                        |
| Calcium carbide                                            |                                                                      |
| Calcium chloride                                           | Diatomaceous earth                                                   |
| Calcium nickel phosphate stabilized with 2% Chromium oxide | Dichlorohydrin                                                       |
| Calcium oxide                                              | Disulfides                                                           |
| Carbon                                                     | Dowex 50 ion exchange resin                                          |

Table C-1. (Continued). CATALYSTS USED IN THE  
PRODUCTION OF INDUSTRIAL ORGANIC CHEMICALS

Ethyl acetate

Ferric acetate

Ferric bromide

Ferric chloride

Ferric oxide-chromium oxide-potassium oxide

Friedel-Crafts reagents

Fuller's earth

Gamma radiation from Cobalt-60

Heavy metal salts

Hydrochloric acid

Ion exchange resins

Iron turnings

Iron-molybdenum oxide

Lewis acid catalyst

Light

Lithium arsenate

Lithium phosphate

Lithium "salt"

Magnesium

Magnesium oxide

Manganese acetate

Manganese butyrate

Manganese oxide

Mercaptans

Metaboric acid

Molybdenum chloride

Molybdenum oxides

Molybdenum sulfide

Nickel

Nickel, activated

Nickel, activated, on asbestos carrier

Nickel-chromium catalyst, reduced

Nickel acetate

Nickel oxide in refractory cement

Nickel chromite

Nickel chromate

Nickel, Raney

Nickel sulfide

Oleic acid

Palladium

Palladium catalyst, supported

Palladium chloride promoted for metal  
oxidation by copper chloride

Phosphoric acid, solid

Phosphoric acid, on kieselguhr

Phosphorus, red

Phosphorous trichloride

Phosphorous pentachloride

Platinum

Platinum-rhodium mesh

Platinum oxide

Potassium carbonate

Potassium cyanide

Potassium hydroxide

Potassium sulfate

Rhodium-carbonyl complex

Silica-alumina

Silica gel catalyst

Table C-1. (Continued). CATALYSTS USED IN THE  
PRODUCTION OF INDUSTRIAL ORGANIC CHEMICALS

Silica-zirconia

Sodamine

Sodium

Sodium hydroxide

Silver

Silver, crystalline

Silver oxide

Sulfuric acid

Tin

p-Toluene sulfonic acid

Triethyl phosphate

Tungsten

Tungsten sulfide

Tungstic acid

UV light from mercury vapor lamps

Uranium oxide

Vanadium

Vanadium pentoxide

Water

Zinc chloride

Zinc compounds

Zinc oxide promoted with alumina and chromates

Zinc oxide on pumice

Zirconium chloride

APPENDIX D  
INDUSTRIAL ORGANIC CHEMICALS



Table D-1. INDUSTRIAL ORGANIC CHEMICALS

NAME

ACETAL  
ACETALDEHYDE  
ACETALDOL  
ACETAMIDE  
ACETANILIDE  
ACETIC ACID  
ACETIC ANHYDRIDE  
ACETONE  
ACETONE CYANOHYDRIN  
ACETONITRILE  
ACETOPHENONE  
ACETYL CHLORIDE  
ACETYLENE  
ACROLEIN  
ACRYLAMIDE  
ACRYLIC ACID AND ACRYLATE ESTERS  
ACRYLONITRILE  
ADIPIC ACID  
ADIPONITRILE  
ALKYLNAPHTHALENES (METHYL)  
ALLYL ALCOHOL  
ALLYL CHLORIDE  
AMINO BENZOIC ACID (M,P)  
AMINOETHYLETHANOLAMINE  
P-AMINOPHENOL  
AMYL ACETATES  
AMYL ALCOHOLS (8 ISOMERS)  
AMYLAMINE  
AMYL CHLORIDE  
AMYL MERCAPTANS  
AMYL PHENOL  
ANILINE  
ANILINE HYDROCHLORIDE  
ANISIDINE  
ANISOLE  
ANTHRANILIC ACID  
ANTHRAQUINONE  
BENZALDEHYDE



Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

BENZAMIDE  
BENZENE  
BENZENEDISULFONIC ACID  
BENZENESULFONIC ACID  
BENZIL  
BENZILIC ACID  
BENZOIC ACID  
BENZOIN  
BENZONITRILE  
BENZOPHENONE  
BENZOTRICHLORIDE  
BENZOYL CHLORIDE  
BENZYL ALCOHOL  
BENZYLAMINE  
BENZYL BENZOATE  
BENZYL CHLORIDE  
BENZYL DICHLORIDE  
BIPHENYL  
BISPHENOL A  
BROMOBENZENE  
BROMONAPHTHALENE  
BUTADIENE  
1-BUTENE  
N-BUTYLACETATE  
N-BUTYLACRYLATE  
N-BUTYL ALCOHOL  
SEC-BUTYL ALCOHOL  
TERT-BUTYL ALCOHOL  
N-BUTYLAMINE  
SEC-BUTYLAMINE  
TERT-BUTYLAMINE  
P-TERT-BUTYLBENZOIC ACID  
1,3 BUTYLENE GLYCOL  
TERT-BUTYLPHENOL  
N-BUTYRALDEHYDE  
N-BUTYRIC ACID  
N-BUTYRIC ANHYDRIDE  
N-BUTYRONITRILE

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

CAPROLACTAM  
CARBON DISULFIDE  
CARBON TETRABROMIDE  
CARBON TETRACHLORIDE  
CELLULOSE ACETATE  
CHLOROACETIC ACID  
M-CHLOROANILINE  
O-CHLOROANILINE  
P-CHLOROANILINE  
CHLOROBENZALDEHYDE  
CHLOROBENZENE  
CHLOROBENZOIC ACID  
CHLOROBENZOTRICHLORIDE (O,P)  
CHLOROBENZOYL CHLORIDE  
CHLORODIFLUOROETHANE  
CHLORODIFLUOROMETHANE  
CHLOROFORM  
CHLORONAPHTHALENE  
O-CHLORONITROBENZENE  
P-CHLORONITROBENZENE  
CHLOROPHENOLS  
CHLOROSULFONIC ACID  
M-CHLOROTOLUENE  
O-CHLOROTOLUENE  
P-CHLOROTOLUENE  
CHLOROTRIFLUOROMETHANE  
CROTONALDEHYDE  
CROTONIC ACID  
CUMENE  
CUMENE HYDROPEROXIDE  
CYANOACETIC ACID  
CYANOGEN CHLORIDE  
CYANURIC ACID  
CYANURIC CHLORIDE  
CYCLOHEXANE  
CYCLOHEXANOL  
CYCLOHEXANONE  
CYCLOHEXENE

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

CYCLOHEXYLAMINE  
 CYCLOOCTADIENE  
 DECANOL  
 DIACETONE ALCOHOL  
 DIAMINOBENZOIC ACID  
 DICHLOROANILINE  
 M-DICHLOROBENZENE  
 O-DICHLOROBENZENE  
 P-DICHLOROBENZENE  
 DICHLORODIFLUOROMETHANE  
 1,2-DICHLOROETHANE  
 DICHLOROETHYL ETHER  
 DICHLOROHYDRIN  
 DICHLOROPROPENE  
 DICYCLOHEXYLAMINE  
 DIETHYLAMINE  
 DIETHYLENE GLYCOL  
 DIETHYLENE GLYCOL DIETHYL ETHER  
 DIETHYLENE GLYCOL DIMETHYL ETHER  
 DIETHYLENE GLYCOL MONOBUTYL ETHER  
 DIETHYLENE GLYCOL MONOBUTYL ETHER ACETATE  
 DIETHYLENE GLYCOL MONOETHYL ETHER  
 DIETHYLENE GLYCOL MONOETHYL ETHER ACETATE  
 DIETHYLENE GLYCOL MONOMETHYL ETHER  
 DIETHYL SULFATE  
 DIFLUOROETHANE  
 DIISOBUTYLENE  
 DIKETENE  
 DIMETHYLAMINE  
 N,N-DIMETHYLANILINE  
 DIMETHYL ETHER  
 N,N-DIMETHYLFORMAMIDE  
 DIMETHYL HYDRAZINE  
 DIMETHYL SULFATE  
 DIMETHYL SULFIDE  
 DIMETHYL SULFOXIDE  
 DIMETHYL TEREPHTHALATE  
 3,5-DINITROBENZOIC ACID

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

2,4-DINITROPHENOL  
 DINITROTOLUENE  
 DIOXANE  
 DIOXOLANE  
 DIPHENYLAMINE  
 DIPHENYL OXIDE  
 DIPHENYLTHIOUREA  
 DIPROPYLENE GLYCOL  
 DODECENE  
 DODECYLANILINE  
 DODECYLPHENOL  
 EPICHLOROHYDRIN  
 ETHANOL  
 ETHANOLAMINE  
 ETHYL ACETATE  
 ETHYL ACETOACETATE  
 ETHYL ACRYLATE  
 ETHYLAMINE  
 ETHYLBENZENE  
 ETHYL BROMIDE  
 ETHYL CELLULOSE  
 ETHYL CHLORIDE  
 ETHYL CHLOROACETATE  
 ETHYLCYANOACETATE  
 ETHYLENE CARBONATE  
 ETHYLENE CHLOROHYDRIN  
 ETHYLENE DIAMINE  
 ETHYLENE DIBROMIDE  
 ETHYLENE GLYCOL  
 ETHYLENE GLYCOL DIACETATE  
 ETHYLENE GLYCOL DIMETHYL ETHER  
 ETHYLENE GLYCOL MONOBUTYL ETHER  
 ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE  
 ETHYLENE GLYCOL MONOETHYL ETHER  
 ETHYLENE GLYCOL MONOETHYL ETHER ACETATE  
 ETHYLENE GLYCOL MONOMETHYL ETHER  
 ETHYLENE GLYCOL MONOMETHYL ETHER ACETATE  
 ETHYLENE GLYCOL MONOPHENYL ETHER

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

ETHYLENE GLYCOL MONOPROPYL ETHER  
 ETHYLENE OXIDE  
 ETHYL ETHER  
 2-ETHYL HEXANOL  
 ETHYL ORTHOFORMATE  
 ETHYL OXALATE  
 ETHYL SODIUM OXALACETATE  
 FORMALDEHYDE  
 FORMAMIDE  
 FORMIC ACID  
 FUMARIC ACID  
 GLYCEROL (NATURAL & SYNTHETIC)  
 GLYCEROL DICHLOROHYDRIN  
 GLYCEROL TRI (POLYOXYPROPYLENE) ETHER  
 GLYCINE  
 GLYOXAL  
 HEPTENE  
 HEXACHLOROBENZENE  
 HEXACHLOROETHANE  
 HEXADECYL ALCOHOL  
 HEXAMETHYLENEDIAMINE  
 HEXAMETHYLENE GLYCOL  
 HEXAMETHYLENE TETRAMINE  
 HYDROGEN CYANIDE  
 HYDROQUINONE  
 P-HYDROXYBENZOIC ACID  
 ISOAMYLENE  
 ISOBUTANOL  
 ISOBUTYL ACETATE  
 ISOBUTYLENE  
 ISOBUTYRALDEHYDE  
 ISOBUTYRIC ACID  
 ISODECANOL  
 ISOOCTYL ALCOHOL  
 ISOPENTANE  
 ISOPHORONE  
 ISOPHTHALIC ACID  
 ISOPRENE

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

ISOPROPANOL  
 ISOPROPYL ACETATE  
 ISOPROPYLAMINE(MONO)  
 ISOPROPYL CHLORIDE  
 ISOPROPYLPHENOL  
 KETENE  
 MALEIC ACID  
 MALEIC ANHYDRIDE  
 MALIC ACID  
 MEBITYL OXIDE  
 METANILIC ACID  
 METHACRYLIC ACID  
 METHALLYL CHLORIDE  
 METHANOL  
 METHYL ACETATE  
 METHYL ACETOACETATE  
 METHYLAMINE  
 N-METHYLANILINE  
 METHYL BUTYNOL  
 METHYL CHLORIDE  
 METHYLCYCLOHEXANE  
 METHYLCYCLOHEXANONE  
 METHYLENE CHLORIDE  
 METHYLENE DIANILINE  
 METHYL ETHYL KETONE  
 METHYL FORMATE  
 METHYLISOBUTYL CARBINOL  
 METHYLISOBUTYL KETONE  
 METHYL METHACRYLATE  
 METHYLPENTYNOL  
 A-METHYLSTYRENE  
 MORPHOLINE  
 A-NAPHTHALENE SULFONIC ACID  
 B-NAPHTHALENE SULFONIC ACID  
 A-NAPHTHOL  
 B-NAPHTHOL  
 NEOPENTANOIC ACID  
 O-NITROANILINE

Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

P-NITROANILINE  
 O-NITROANISOLE  
 P-NITROANISOLE  
 NITROBENZENE  
 NITROBENZOIC ACID (M,O,P)  
 NITROETHANE  
 NITROMETHANE  
 NITROPHENOL  
 NITROPROPANE  
 NITROTOLUENE  
 NONENE  
 NONYLPHENOL  
 OCTYLPHENOL  
 PARALDEHYDE  
 PENTAERYTHRITOL  
 N-PENTANE  
 1-PENTENE  
 PERCHLOROETHYLENE  
 PERCHLOROMETHYL MERCAPTAN  
 O-PHENETIDINE  
 P-PHENETIDINE  
 PHENOL  
 PHENOLSULFONIC ACIDS  
 PHENYL ANTHRANILIC ACID  
 PHENYLENEDIAMINE  
 PHOSGENE  
 PHTHALIC ANHYDRIDE  
 PHTHALIMIDE  
 O-PICOLINE  
 PIPERAZINE  
 POLYBUTENES  
 POLYETHYLENE GLYCOL  
 POLYPROPYLENE GLYCOL  
 PROPIONALDEHYDE  
 PROPIONIC ACID  
 N-PROPYL ALCOHOL  
 PROPYLAMINE  
 PROPYL CHLORIDE



Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

PROPYLENE  
 PROPYLENE CHLOROHYDRIN  
 PROPYLENE DICHLORIDE  
 PROPYLENE GLYCOL  
 PROPYLENE OXIDE  
 PYRIDINE (NATURAL & SYNTHETIC)  
 QUINONE  
 RESORCINOL  
 RESORCYLIC ACID  
 SALICYLIC ACID  
 SODIUM ACETATE  
 SODIUM BENZOATE  
 SODIUM CARBOXYMETHYL CELLULOSE  
 SODIUM CHLOROACETATE  
 SODIUM FORMATE  
 SODIUM PHENATE  
 SORBIC ACID  
 STYRENE  
 SUCCINIC ACID  
 SUCCINONITRILE  
 SULFANILIC ACID  
 SULFOLANE  
 TANNIC ACID  
 TEREPHTHALIC ACID  
 TETRACHLOROETHANE  
 TETRACHLOROPHTHALIC ANHYDRIDE  
 TETRAETHYL LEAD  
 TETRAHYDRONAPHTHALENE  
 TETRAHYDROPHTHALIC ANHYDRIDE  
 TETRAMETHYLENEDIAMINE  
 TETRAMETHYLETHYLENEDIAMINE  
 TOLUENE  
 TOLUENE-2,4-DIAMINE  
 2,4-TOLUENE DIISOCYANATE  
 TOLUENE DIISOCYANATES(MIXTURE)  
 TOLUENESULFONAMIDE  
 TOLUENESULFONIC ACIDS  
 TOLUENESULFONYL CHLORIDE



Table D-1. (Continued). INDUSTRIAL ORGANIC CHEMICALS

NAME

TOLUIDINES  
TRICHLOROBENZENE  
1,1,1-TRICHLOROETHANE  
1,1,2-TRICHLOROETHANE  
TRICHLOROETHYLENE  
TRICHLOROFLUOROMETHANE  
1,2,3-TRICHLOROPROPANE  
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE  
TRIETHYLAMINE  
TRIETHYLENE GLYCOL  
TRIETHYLENE GLYCOL DIMETHYL ETHER  
TRIISOBUTYLENE  
TRIMETHYLAMINE  
UREA  
VINYL ACETATE  
VINYL CHLORIDE  
VINYLIDENE CHLORIDE  
VINYL TOLUENE  
XYLENES, MIXED  
O-XYLENE  
P-XYLENE  
XYLENOL  
XYLIDINE

APPENDIX E  
INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

Table E-1. INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                              | CITY          | STATE |
|-----------------------------------|---------------|-------|
| ABBOTT LABORATORIES               | NORTH CHICAGO | IL    |
| ACETO CHEMICAL CO. INC.           | CARLSTADT     | NJ    |
| ACME-HARDESTY CO. INC.            | JENKINTOWN    | PA    |
| ADD PROCESSING CORP.              | ABBEVILLE     | LA    |
| AGWAY, INC                        | OLEAN         | NY    |
| AIRCO CHEMICALS AND PLASTICS      | LOUISVILLE    | KY    |
| AIR PRODUCTS AND CHEMICALS INC.   | CALVERT CITY  | KY    |
| AIR PRODUCTS AND CHEMICALS INC.   | HOMETOWN      | PA    |
| AIR PRODUCTS AND CHEMICALS INC.   | PASADENA      | TX    |
| AIR PRODUCTS AND CHEMICALS INC.   | PENSACOLA     | FL    |
| AKZONA INC.                       | LOWLAND       | TN    |
| ALBA MANUFACTURING CO.            | AURORA        | IL    |
| ALCO STANDARD CORP.               | EDDYSTONE     | PA    |
| ALDRICH CHEMICAL CO.              | MILWAUKEE     | WI    |
| ALLIED CHEMICAL CORP.             | BATON ROUGE   | LA    |
| ALLIED CHEMICAL CORP.             | BUFFALO       | NY    |
| ALLIED CHEMICAL CORP.             | DANVILLE      | IL    |
| ALLIED CHEMICAL CORP.             | ELIZABETH     | NJ    |
| ALLIED CHEMICAL CORP.             | EL SEGUNDO    | CA    |
| ALLIED CHEMICAL CORP.             | FRANKFORD     | PA    |
| ALLIED CHEMICAL CORP.             | GEISMAR       | LA    |
| ALLIED CHEMICAL CORP.             | KOPEWELL      | VA    |
| ALLIED CHEMICAL CORP.             | MARCUS HOOK   | PA    |
| ALLIED CHEMICAL CORP.             | MOUNDSVILLE   | WV    |
| ALLIED CHEMICAL CORP.             | OMAHA         | NE    |
| ALLIED CHEMICAL CORP.             | ORANGE        | TX    |
| ALLIED CHEMICAL CORP.             | SOUTH POINT   | OH    |
| ALLIED CHEMICAL CORP.             | SYRACUSE      | NY    |
| AMERICAN ANILINE AND EXTRACT CO.  | PHILADELPHIA  | PA    |
| AMERICAN COLOR AND CHEMICAL CORP. | LOCK HAVEN    | PA    |
| AMERICAN CYANAMID CO.             | BOUND BROOK   | NJ    |
| AMERICAN CYANAMID CO.             | CHARLOTTE     | NC    |
| AMERICAN CYANAMID CO.             | LINDEN        | NJ    |
| AMERICAN CYANAMID CO.             | MARIETTA      | OH    |
| AMERICAN CYANAMID CO.             | NEW ORLEANS   | LA    |
| AMERICAN CYANAMID CO.             | WILLOW ISLAND | WV    |
| AMERICAN HOECHST CORP.            | COVENTRY      | RI    |
| AMERICAN PETROFINA INC.           | BIG SPRING    | TX    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                      | CITY           | STATE |
|---------------------------|----------------|-------|
| AMERICAN POLYMERS INC.    | PATTERSON      | NJ    |
| AMES LABORATORIES INC.    | MILFORD        | CT    |
| ANSUL CO.                 | MARINETTE      | WI    |
| ARCO CHEMICAL CO.         | BEAVER VALLEY  | PA    |
| ARCO CHEMICAL CO.         | CHANNELVIEW    | TX    |
| ARCO CHEMICAL CO.         | EAST CHICAGO   | IN    |
| ARCO CHEMICAL CO.         | HOUSTON        | TX    |
| ARCO CHEMICAL CO.         | PORT ARTHUR    | TX    |
| ARCO CHEMICAL CO.         | WILMINGTON     | CA    |
| ARCO/POLYMERS INC.        | HOUSTON        | TX    |
| ARMOUR AND COMPANY        | MONTGOMERY     | IL    |
| ASHLAND CHEMICAL CO.      | ASHLAND        | KY    |
| ASHLAND CHEMICAL CO.      | GREAT MEADOWS  | NJ    |
| ASHLAND CHEMICAL CO.      | HAMMOND        | IN    |
| ASHLAND CHEMICAL CO.      | JANESVILLE     | WI    |
| ASHLAND CHEMICAL CO.      | MAPLETON       | IL    |
| BASF WYANDOTTE CORP.      | GEISHAR        | LA    |
| BASF WYANDOTTE CORP.      | KEARNY         | NJ    |
| BASF WYANDOTTE CORP.      | WASHINGTON     | NJ    |
| BASF WYANDOTTE CORP.      | WYANDOTTE      | MI    |
| BECKMAN INSTRUMENTS, INC. | PALO ALTO      | CA    |
| BEKER INDUSTRIES CORP.    | CARLSBAD       | NM    |
| BETHLEHEM STEEL CORP.     | SPARROWS POINT | MD    |
| BIO-RAD LABORATORIES      | RICHMOND       | CA    |
| BLUE SPRUCE CO.           | EDISON         | NJ    |
| BQFORS INDUSTRIES INC.    | LINDEN         | NJ    |
| BORDEN CHEMICAL           | BAINBRIDGE     | NY    |
| BORDEN CHEMICAL           | COMPTON        | CA    |
| BORDEN CHEMICAL           | DEMOPOLIS      | AL    |
| BORDEN CHEMICAL           | DIBOLL         | TX    |
| BORDEN CHEMICAL           | FAYETTEVILLE   | NC    |
| BORDEN CHEMICAL           | FREMONT        | CA    |
| BORDEN CHEMICAL           | GEISHAR        | LA    |
| BORDEN CHEMICAL           | ILLIOPOLIS     | IL    |
| BORDEN CHEMICAL           | KENT           | WA    |
| BORDEN CHEMICAL           | LA GRANDE      | OR    |
| BORDEN CHEMICAL           | LEOMINSTER     | MA    |
| BORDEN CHEMICAL           | LOUISVILLE     | KY    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                                | CITY           | STATE |
|-------------------------------------|----------------|-------|
| BORDEN CHEMICAL                     | MISSOULA       | MT    |
| BORDEN CHEMICAL                     | SHEBOYGAN      | WI    |
| BORDEN CHEMICAL                     | SPRINGFIELD    | OR    |
| BORG-WARNER CORP.                   | MORGANTOWN     | WV    |
| BROWN CO.                           | BERLIN         | NH    |
| BUCKMAN LABORATORIES INC.           | CADET          | MO    |
| BUCKMAN LABORATORIES INC.           | MEMPHIS        | TN    |
| CALCASIEU CHEMICAL CORP.            | LAKE CHARLES   | LA    |
| CARIBE ISOPRENE CORP.               | PONCE          | PR    |
| CARUS CORP.                         | LASALLE        | IL    |
| CELANESE CHEMICAL CO.               | BAY CITY       | TX    |
| CELANESE CHEMICAL CO.               | BISHOP         | TX    |
| CELANESE CHEMICAL CO.               | CLEAR LAKE     | TX    |
| CELANESE CHEMICAL CO.               | NARROWS        | VA    |
| CELANESE CHEMICAL CO.               | NEWARK         | NJ    |
| CELANESE CHEMICAL CO.               | PAMPA          | TX    |
| CELANESE CHEMICAL CO.               | ROCK HILL      | SC    |
| CELANESE CHEMICAL CO.               | ROME           | GA    |
| CF INDUSTRIES                       | DONALDSONVILLE | LA    |
| CF INDUSTRIES                       | FREEMONT       | NE    |
| CF INDUSTRIES                       | TUNIS          | NC    |
| CF INDUSTRIES                       | TYNER          | TN    |
| CHARTER CHEMICALS                   | HOUSTON        | TX    |
| CHATTEN DRUG AND CHEMICAL CO.       | CHATTANOOGA    | TN    |
| CHATTEN DRUG AND CHEMICAL CO.       | LONG BEACH     | CA    |
| CHEMETRON CHEMICALS                 | LAPORTE        | TX    |
| CHEMICAL FORMULATORS INC.           | NITRO          | WV    |
| CHEMICAL & POLLUTION SCIENCES, INC. | OLD BRIDGE     | NJ    |
| CHEMICAL PRODUCTS CORP.             | CARTERSVILLE   | GA    |
| CHEMOL INC.                         | GREENSBORO     | NC    |
| CHEMPLEX CO.                        | CLINTON        | IA    |
| CHEVRON CHEMICAL CO.                | EL SEGUNDO     | CA    |
| RICHMOND CHEMICAL CO.               | RICHMOND       | CA    |
| CHICAGO SANITARY PRODUCTS CO.       | CHICAGO        | IL    |
| CIBA-GEIGY CORP                     | MCINTOSH       | AL    |
| CIBA-GEIGY CORP                     | ST. GABRIEL    | LA    |
| CITIES SERVICE CO INC               | COPPERHILL     | TN    |
| CITIES SERVICE CO INC               | LAKE CHARLES   | LA    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                                | CITY           | STATE |
|-------------------------------------|----------------|-------|
| CLARK CHEMICAL CO.                  | BLUE ISLAND    | IL    |
| CLORAY NJ CORP.                     | NEWARK         | NJ    |
| COASTAL STATES GAS CO.              | CHEYENNE       | WY    |
| COASTAL STATES GAS CO.              | CORPUS CHRISTI | TX    |
| COLGATE PALMOLIVE CO.               | BERKELY        | CA    |
| COLGATE PALMOLIVE CO.               | JEFFERSONVILLE | IN    |
| COLGATE PALMOLIVE CO.               | JERSEY CITY    | NJ    |
| COLGATE PALMOLIVE CO.               | KANSAS CITY    | KA    |
| COLT INDUSTRIES INC.                | MIDLAND        | PA    |
| COLUMBIA NITROGEN CORP.             | AUGUSTA        | GA    |
| COMMERCIAL SOLVENTS CORP.           | SEIPLE         | PA    |
| COMMERCIAL SOLVENTS CORP.           | STERLINGTON    | LA    |
| COMMERCIAL SOLVENTS CORP.           | TERRE HAUTE    | IN    |
| COMMONWEALTH OIL REFINING CO.       | PENUELAS       | PR    |
| CONTINENTAL OIL COMPANY             | NEWARK         | NJ    |
| CONTINENTAL OIL COMPANY             | WESTLAKE       | LA    |
| COOPERATIVE FARM CHEMICAL ASSOC.    | LAWRENCE       | KA    |
| COPOLYMER RUBBER AND CHEMICAL CORP. | BATON ROUGE    | LA    |
| COS-MAR INC                         | CARVILLE       | LA    |
| CROMPTON & KNOWLES CORP.            | GIBRALTAR      | PA    |
| CROMPTON & KNOWLES CORP.            | READING        | PA    |
| CROWLEY HYDROCARBON CHEMICALS INC.  | HOUSTON        | TX    |
| CROWLEY HYDROCARBON CHEMICALS INC.  | KENT           | OH    |
| CROWLEY HYDROCARBON CHEMICALS INC.  | OKLAHOMA CITY  | OK    |
| CROWLEY TAR PRODUCTS                | BALTIMORE      | MD    |
| CROWLEY TAR PRODUCTS                | HOUSTON        | TX    |
| CROWN ZELLERBACH CORP.              | BOGALUSA       | LA    |
| CROWN ZELLERBACH CORP.              | CAMAS          | WA    |
| DAN RIVER INC.                      | DANVILLE       | VA    |
| DARLING AND CO.                     | CHICAGO        | IL    |
| DART INDUSTRIES INC.                | ELYRIA         | OH    |
| DIAMOND SHAMROCK CORP.              | BELLE          | WV    |
| DIAMOND SHAMROCK CORP.              | CEDARTOWN      | GA    |
| DIAMOND SHAMROCK CORP.              | DEER PARK      | TX    |
| DIXIE CHEMICAL CO                   | BAYPORT        | TX    |
| DON CHEMICAL CO.                    | ANCHORAGE      | AK    |
| DDW BADISCHE CO.                    | FREEMPORT      | TX    |
| DDW CHEMICAL CO.                    | BAY CITY       | MI    |



Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                          | CITY             | STATE |
|-------------------------------|------------------|-------|
| DOW CHEMICAL CO,              | FREEPORT         | TX    |
| DOW CHEMICAL CO,              | MAGNOLIA         | AR    |
| DOW CHEMICAL CO,              | MIDLAND          | MI    |
| DOW CHEMICAL CO,              | OYSTER CREEK     | TX    |
| DOW CHEMICAL CO,              | PITTSBURG        | CA    |
| DOW CHEMICAL CO,              | PLAQUEMINE       | LA    |
| DOW CORNING                   | CARROLLTON       | KY    |
| DOW CORNING                   | MIDLAND          | MI    |
| EI DU PONT DE NEMOURS & CO    | ANTIOCH          | CA    |
| EI DU PONT DE NEMOURS & CO    | BEAUMONT         | TX    |
| EI DU PONT DE NEMOURS & CO    | BELLE            | WV    |
| EI DU PONT DE NEMOURS & CO    | CAPE FEAR        | NC    |
| EI DU PONT DE NEMOURS & CO    | CORPUS CHRISTI   | TX    |
| EI DU PONT DE NEMOURS & CO    | DEEPWATER POINT  | NJ    |
| EI DU PONT DE NEMOURS & CO    | EAST CHICAGO     | IN    |
| EI DU PONT DE NEMOURS & CO    | GIBBSTOWN        | NJ    |
| EI DU PONT DE NEMOURS & CO    | HEALING SPRINGS  | NC    |
| EI DU PONT DE NEMOURS & CO    | LAPLACE          | LA    |
| EI DU PONT DE NEMOURS & CO    | LAPORTE          | TX    |
| EI DU PONT DE NEMOURS & CO    | LINDEN           | NJ    |
| EI DU PONT DE NEMOURS & CO    | LOUISVILLE       | KY    |
| EI DU PONT DE NEMOURS & CO    | MEMPHIS          | TN    |
| EI DU PONT DE NEMOURS & CO    | MONTAGUE         | MI    |
| EI DU PONT DE NEMOURS & CO    | NIAGARA FALLS    | NY    |
| EI DU PONT DE NEMOURS & CO    | ORANGE           | TX    |
| EI DU PONT DE NEMOURS & CO    | TOLEDO           | OH    |
| EI DU PONT DE NEMOURS & CO    | VICTORIA         | TX    |
| EI DU PONT DE NEMOURS & CO    | WAYNESBORO       | VA    |
| DYE SPECIALTIES INC           | JERSEY CITY      | NJ    |
| EASTERN COLOR AND CHEMICAL CO | PROVIDENCE       | RI    |
| EASTMAN KODAK CO,             | KINGSPORT        | TN    |
| EASTMAN KODAK CO,             | LONGVIEW         | TX    |
| EASTMAN KODAK CO,             | ROCHESTER        | NY    |
| EL PASO NATURAL GAS CO,       | ODESSA           | TX    |
| EMERY INDUSTRIES INC,         | CINCINNATI       | OH    |
| EMERY INDUSTRIES INC,         | CITY OF COMMERCE | CA    |
| EMKAY CHEMICAL CO,            | ELIZABETH        | NJ    |
| ENSERCH CORP,                 | KERENS           | TX    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                          | CITY             | STATE |
|-------------------------------|------------------|-------|
| ENSERCH CORP.                 | PRYOR            | OK    |
| ESMARK, INC.                  | BEAUMONT         | TX    |
| ESMARK, INC.                  | WINCHESTER       | MA    |
| ETHYL CORP.                   | BATON ROUGE      | LA    |
| ETHYL CORP.                   | MAGNOLIA         | AR    |
| ETHYL CORP.                   | ORANGEBURG       | SC    |
| ETHYL CORP.                   | PASADENA         | TX    |
| EXXON CHEMICAL CO.            | BATON ROUGE      | LA    |
| EXXON CHEMICAL CO.            | BAYTOWN          | TX    |
| EXXON CHEMICAL CO.            | BAYWAY           | NJ    |
| FAIRMONT CHEMICAL CO.         | NEWARK           | NJ    |
| FERRO CORP.                   | BATON ROUGE      | LA    |
| FERRO CORP.                   | SANTA FE SPRINGS | CA    |
| FIRESTONE TIRE AND RUBBER CO. | ORANGE           | TX    |
| FIRST MISSISSIPPI CORP.       | PASCAGOULA       | MS    |
| FLEMING LABORATORIES INC.     | CHARLOTTE        | NC    |
| FMC CORP.                     | BALTIMORE        | MD    |
| FMC CORP.                     | BAYPORT          | TX    |
| FMC CORP.                     | MEADVILLE        | PA    |
| FMC CORP.                     | SOUTH CHARLESTON | WV    |
| FOSTER-GRANT CO. INC.         | BATON ROUGE      | LA    |
| FRANK ENTERPRISES             | COLUMBUS         | OH    |
| FRITZCHE DODGE & OLCOTT INC.  | EAST HANOVER     | NJ    |
| GAF CORP.                     | CALVERT CITY     | KY    |
| GAF CORP.                     | LINDEN           | NJ    |
| GAF CORP.                     | RENNSELEAR       | NY    |
| GARDINIER BIG RIVER, INC.     | HELENA           | AR    |
| GENERAL AMERICAN OIL OF TEXAS | PASADENA         | TX    |
| GENERAL ELECTRIC CO.          | MOUNT VERNON     | IN    |
| GENERAL ELECTRIC CO.          | SELKIRK          | NY    |
| GENERAL ELECTRIC CO.          | WATERFORD        | NY    |
| THE GENERAL TIRE & RUBBER CO. | ASHTABULA        | OH    |
| GEORGIA PACIFIC CORP.         | ALBANY           | OR    |
| GEORGIA PACIFIC CORP.         | BELLINGHAM       | WA    |
| GEORGIA PACIFIC CORP.         | COLUMBUS         | OH    |
| GEORGIA PACIFIC CORP.         | COOS BAY         | OR    |
| GEORGIA PACIFIC CORP.         | CROSSETT         | AR    |
| GEORGIA PACIFIC CORP.         | PLAQUEMINE       | LA    |



Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                            | CITY               | STATE |
|---------------------------------|--------------------|-------|
| GEORGIA PACIFIC CORP.           | RUSSELLVILLE       | SC    |
| GEORGIA PACIFIC CORP.           | TAYLORSVILLE       | MS    |
| GEORGIA PACIFIC CORP.           | VIENNA             | GA    |
| GETTY OIL CO.                   | DELAWARE CITY      | DE    |
| GIVAUDAN CORP.                  | CLIFTON            | NJ    |
| GOODPASTURE, INC.               | DIMMITT            | TX    |
| BF GOODRICH CHEMICAL CO.        | CALVERT CITY       | KY    |
| BF GOODRICH CHEMICAL CO.        | HENRY              | IL    |
| BF GOODRICH CHEMICAL CO.        | PORT NECHES        | TX    |
| GOODYEAR TIRE AND RUBBER CO.    | BAYPORT            | TX    |
| GOODYEAR TIRE AND RUBBER CO.    | BEAUMONT           | TX    |
| W. R. GRACE AND CO.             | FORDS              | NJ    |
| W. R. GRACE AND CO.             | MEMPHIS            | TN    |
| W. R. GRACE AND CO.             | NASHUA             | NH    |
| GRAIN PROCESSING CORP.          | MUSCATINE          | IA    |
| GREAT LAKES CHEMICAL CORP.      | EL DORADO          | AR    |
| GUARDIAN CHEMICAL CORP.         | HAUPPAUGE          | NY    |
| GULF OIL CO.                    | ALLIANCE           | LA    |
| GULF OIL CO.                    | CEDAR BAYOU        | TX    |
| GULF OIL CO.                    | PHILADELPHIA       | PA    |
| GULF OIL CO.                    | PORT ARTHUR        | TX    |
| GULF OIL CO.                    | VICKSBURG          | MS    |
| GULF OIL CO.                    | WELCOME            | LA    |
| HARDWICKE CHEMICAL CO.          | ELGIN              | SC    |
| HEICO, INC.                     | DELAWARE WATER GAP | PA    |
| HERCULES, INC.                  | BURLINGTON         | NJ    |
| HERCULES, INC.                  | GIBBSTOWN          | NJ    |
| HERCULES, INC.                  | GLENN FALLS        | NY    |
| HERCULES, INC.                  | HARBOR BEACH       | MI    |
| HERCULES, INC.                  | HERCULES           | CA    |
| HERCULES, INC.                  | HOPEWELL           | VA    |
| HERCULES, INC.                  | LOUISIANA          | MO    |
| HERCULES, INC.                  | PLAQUEMINE         | LA    |
| HERCULES, INC.                  | WILMINGTON         | NC    |
| HODAG CHEMICAL CORP.            | SKOKIE             | IL    |
| HOWERTOWN GOWEN CHEMICALS, INC. | ROANOKE RAPIDS     | NC    |
| HUMMEL CHEMICAL CO.             | SOUTH PLAINFIELD   | NJ    |
| HUMPHREY CHEMICAL CO.           | NORTH HAVEN        | CT    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                         | CITY            | STATE |
|------------------------------|-----------------|-------|
| ICC INDUSTRIES, INC.         | DOVER           | OH    |
| ICC INDUSTRIES, INC.         | NIAGARA FALLS   | NY    |
| ICI UNITED STATES            | NEW CASTLE      | DE    |
| INLAND CHEMICAL CORP.        | JUNEAU          | WI    |
| INLAND CHEMICAL CORP.        | MANATI          | PR    |
| JEFFERSON CHEMICAL CO., INC. | CONROE          | TX    |
| JEFFERSON CHEMICAL CO., INC. | PORT NECHES     | TX    |
| JOC OIL, INC.                | HOUSTON         | TX    |
| ANDREW JERGENS CO.           | CINCINNATI      | OH    |
| KAISER CHEMICALS             | SAVANNAH        | GA    |
| KALAMA CHEMICALS, INC.       | KALAMA          | WA    |
| KAY-FRIES CHEMICALS, INC.    | STONY POINT     | NY    |
| KENANEE INDUSTRIES, INC.     | GLOUCESTER CITY | NJ    |
| H. KOHNSTAMM AND CO., INC.   | CAMDEN          | NJ    |
| H. KOHNSTAMM AND CO., INC.   | CLEARING        | IL    |
| KOPPERS CO., INC.            | BRIDGEVILLE     | PA    |
| KOPPERS CO., INC.            | CICERO          | IL    |
| KOPPERS CO., INC.            | FOLLANSBEE      | WV    |
| KOPPERS CO., INC.            | PETROLIA        | PA    |
| KRAFTCO CORP.                | MEMPHIS         | TN    |
| LACAT CHEMICALS INC.         | CHICAGO HEIGHTS | IL    |
| LEVER BROTHERS CO.           | BALTIMORE       | MO    |
| LEVER BROTHERS CO.           | EDGEWATER       | NJ    |
| LEVER BROTHERS CO.           | HAMMOND         | IN    |
| LEVER BROTHERS CO.           | LOS ANGELES     | CA    |
| LEVER BROTHERS CO.           | ST. LOUIS       | MO    |
| ELI LILLY AND CO.            | LAFAYETTE       | IN    |
| LONZA, INC.                  | MAPLETON        | IL    |
| LUBRIZOL CORP.               | DEER PARK       | TX    |
| LUBRIZOL CORP.               | DEER PARK       | TX    |
| MALLINCKRODT, INC.           | LODI            | NJ    |
| MALLINCKRODT, INC.           | RALEIGH         | NC    |
| MALLINCKRODT, INC.           | ST. LOUIS       | MO    |
| MARATHON OIL CO.             | ROBINSON        | IL    |
| MARATHON OIL CO.             | TEXAS CITY      | TX    |
| MARTIN MARIETTA CORP.        | SODYECO         | NC    |
| MERCK AND COMPANY INC.       | ALBANY          | GA    |
| MERICHEM CO.                 | HOUSTON         | TX    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                                   | CITY             | STATE |
|----------------------------------------|------------------|-------|
| MIDDLEBORO INDUSTRIES, INC.            | MIDDLEBORO       | MA    |
| MILES LABORATORIES, INC.               | ZEELAND          | MI    |
| MILLMASTER ONYX CORP.                  | NEWARK           | NJ    |
| MISSISSIPPI CHEMICAL CORP.             | YAZOO            | MS    |
| MOBAY CHEMICAL CO.                     | CEDAR BAYOU      | TX    |
| MOBAY CHEMICAL CO.                     | NEW MARTINSVILLE | WV    |
| MOBIL OIL CORP.                        | BEAUMONT         | TX    |
| MONOCHEM, INC.                         | GEISMAR          | LA    |
| MONSANTO CO.                           | ADDYSTON         | OH    |
| MONSANTO CO.                           | ANNISTON         | AL    |
| MONSANTO CO.                           | BRIDGEPORT       | NJ    |
| MONSANTO CO.                           | CHOCOLATE BAYOU  | TX    |
| MONSANTO CO.                           | DECATUR          | AL    |
| MONSANTO CO.                           | EUGENE           | OR    |
| MONSANTO CO.                           | EVERETT          | MA    |
| MONSANTO CO.                           | KEARNY           | NJ    |
| MONSANTO CO.                           | LULING           | LA    |
| MONSANTO CO.                           | NITRO            | WV    |
| MONSANTO CO.                           | PENSACOLA        | FL    |
| MONSANTO CO.                           | ST. LOUIS        | MO    |
| MONSANTO CO.                           | SAUGET           | IL    |
| MONSANTO CO.                           | SPRINGFIELD      | MA    |
| MONSANTO CO.                           | TEXAS CITY       | TX    |
| MONSANTO CO.                           | TRENTON          | MI    |
| MONTROSE CHEMICAL CORP. OF CALIFORNIA  | HENDERSON        | NV    |
| MURRO CHEMICAL CO.                     | PORTSMOUTH       | VA    |
| NALCO CHEMICAL CO.                     | FREEPORT         | TX    |
| NALCO CHEMICAL CO.                     | SUGARLAND        | TX    |
| NAPP CHEMICALS, INC.                   | LODI             | NJ    |
| NATIONAL DISTILLERS AND CHEMICAL CORP. | DEER PARK        | TX    |
| NATIONAL DISTILLERS AND CHEMICAL CORP. | TUSCULA          | IL    |
| NATIONAL STARCH AND CHEMICAL CORP.     | LONG MOTT        | TX    |
| NATIONAL STEEL CORP.                   | ZUG ISLAND       | MI    |
| NEASE CHEMICAL CO., INC.               | FERNALD          | OH    |
| NEASE CHEMICAL CO., INC.               | STATE COLLEGE    | PA    |
| NECHES BUTANE PRODUCTS CO.             | PORT NECHES      | TX    |
| NIPRO, INC.                            | AUGUSTA          | GA    |
| NORDA, INC.                            | BOONTON          | NJ    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                          | CITY            | STATE |
|-------------------------------|-----------------|-------|
| NORSE LABS, INC.              | SANTA BARBARA   | CA    |
| NORTHERN FINE CHEMICALS       | FRANKLIN        | NJ    |
| NORTHERN NATURAL GAS CO.      | MORRIS          | IL    |
| NORTHWEST INDUSTRIES INC.     | BEAUMONT        | TX    |
| NORTHWEST INDUSTRIES INC.     | CHATTANOOGA     | TN    |
| NORTHWEST INDUSTRIES INC.     | EL DORADO       | AR    |
| NORTHWEST INDUSTRIES INC.     | ST. LOUIS       | MI    |
| N-REN CORP.                   | PLAINVIEW       | TX    |
| N-REN CORP.                   | PRYOR           | OK    |
| OCCIDENTAL PETROLEUM          | ARECIBO         | PR    |
| OCCIDENTAL PETROLEUM          | NIAGARA FALLS   | NY    |
| OCCIDENTAL PETROLEUM          | NORTH TANAWANDA | NY    |
| OCCIDENTAL PETROLEUM          | TAFT            | LA    |
| OLIN CORP.                    | ASHTABULA       | OH    |
| OLIN CORP.                    | BRANDENBURG     | KY    |
| OLIN CORP.                    | LAKE CHARLES    | LA    |
| OLIN CORP.                    | ROCHESTER       | NY    |
| ORBIS PRODUCTS CORP.          | NEWARK          | NJ    |
| OXIRANE CHEMICAL CO.          | BAYPORT         | TX    |
| OXOCHEM ENTERPRISE            | PENUELAS        | PR    |
| PACIFIC SOAP CO.              | VERNON          | CA    |
| PAN AMERICAN CHEMICAL CORP.   | TOLEDO          | OH    |
| PARKE-DAVIS & CO.             | HOLLAND         | MI    |
| PELRON CORP.                  | LYONS           | IL    |
| PENNWALT CORP.                | BEAUMONT        | TX    |
| PENNWALT CORP.                | CALVERT CITY    | KY    |
| PENNWALT CORP.                | GENESEO         | NY    |
| PENNWALT CORP.                | GREENS BAYOU    | TX    |
| PENNWALT CORP.                | THOROFARE       | NJ    |
| PENNWALT CORP.                | WYANDOTTE       | MI    |
| PETRO-TEX CHEMICAL CORP.      | HOUSTON         | TX    |
| PFANSTIEHL LABORATORIES, INC  | WAUKEGAN        | IL    |
| CHAS. PFIZER & CO., INC       | GREENSBORO      | NC    |
| CHAS. PFIZER & CO., INC       | GROTON          | CT    |
| CHAS. PFIZER & CO., INC       | TERRE HAUTE     | IN    |
| PHILLIPS PACIFIC CHEMICAL CO. | KENNENECK       | WA    |
| PHILLIPS PETROLEUM CO.        | BEATRICE        | NE    |
| PHILLIPS PETROLEUM CO.        | BORGER          | TX    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                       | CITY          | STATE |
|----------------------------|---------------|-------|
| PHILLIPS PETROLEUM CO.     | GUAYAMA       | PR    |
| PHILLIPS PETROLEUM CO.     | PHILLIPS      | TX    |
| PHILLIPS PETROLEUM CO.     | SWEENEY       | TX    |
| PIERCE CHEMICAL CO.        | ROCKFORD      | IL    |
| PILOT CHEMICAL CO.         | HOUSTON       | TX    |
| PIONEER SOAP CO.           | SAN FRANCISCO | CA    |
| PLASTICS ENGINEERING CORP. | SHEBOYGAN     | WI    |
| PPG INDUSTRIES, INC.       | BARBERTON     | OH    |
| PPG INDUSTRIES, INC.       | BEAUMONT      | TX    |
| PPG INDUSTRIES, INC.       | GUAYANILLA    | PR    |
| PPG INDUSTRIES, INC.       | LAKE CHARLES  | LA    |
| PPG INDUSTRIES, INC.       | NATRIUM       | WV    |
| PROCTOR & GAMBLE CO.       | BALTIMORE     | MD    |
| PROCTOR & GAMBLE CO.       | CHICAGO       | IL    |
| PROCTOR & GAMBLE CO.       | DALLAS        | TX    |
| PROCTOR & GAMBLE CO.       | DAYTON        | OH    |
| PROCTOR & GAMBLE CO.       | IVORYDALE     | OH    |
| PROCTOR & GAMBLE CO.       | KANSAS CITY   | KA    |
| PROCTOR & GAMBLE CO.       | LONG BEACH    | CA    |
| PROCTOR & GAMBLE CO.       | MEMPHIS       | TN    |
| PROCTOR & GAMBLE CO.       | SACRAMENTO    | CA    |
| PUBLICKER INDUSTRIES INC.  | GRETN         | LA    |
| PUBLICKER INDUSTRIES INC.  | PHILADELPHIA  | PA    |
| PUERTO RICO OLEFINS CO.    | PENUELAS      | PR    |
| PUREX CORP.                | BRISTOL       | PA    |
| PUREX CORP.                | OMAHA         | NE    |
| PYO INTERNATIONAL, INC.    | BOONTON       | NJ    |
| REICHOLD CHEMICALS, INC.   | AUSTIN        | TX    |
| REICHOLD CHEMICALS, INC.   | ELIZABETH     | NJ    |
| REICHOLD CHEMICALS, INC.   | HAMPTON       | SC    |
| REICHOLD CHEMICALS, INC.   | HOUSTON       | TX    |
| REICHOLD CHEMICALS, INC.   | KANSAS CITY   | KA    |
| REICHOLD CHEMICALS, INC.   | MALVERN       | AR    |
| REICHOLD CHEMICALS, INC.   | MONCURE       | NC    |
| REICHOLD CHEMICALS, INC.   | MORRIS        | IL    |
| REICHOLD CHEMICAL INC.     | ST. HELENS    | OR    |
| REICHOLD CHEMICALS, INC.   | TACOMA        | WA    |
| REICHOLD CHEMICALS, INC.   | TUSCALOOSA    | AL    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                       | CITY               | STATE |
|----------------------------|--------------------|-------|
| REICHOLD CHEMICALS, INC.   | WHITE CITY         | OR    |
| REILY TAR & CHEMICAL CORP. | INDIANAPOLIS       | IN    |
| REPUBLIC STEEL CORP.       | CHICAGO            | IL    |
| REPUBLIC STEEL CORP.       | CLEVELAND          | OH    |
| RICHARDSON-MERRELL INC.    | PHILLIPSBURG       | NJ    |
| RITTER CHEMICAL CO.        | AMSTERDAM          | NY    |
| ROBINSON-WAGNER INC.       | MAMARONECK         | NY    |
| ROHM & HAAS CO.            | BRISTOL            | PA    |
| ROHM & HAAS CO.            | DEER PARK          | TX    |
| ROHM & HAAS CO.            | KNOXVILLE          | TN    |
| ROHM & HAAS CO.            | LOUISVILLE         | KY    |
| ROHM & HAAS CO.            | PHILADELPHIA       | PA    |
| R.S.A. CORP.               | ARDSLEY            | NY    |
| RUBICON CHEMICALS INC.     | GEISMAR            | LA    |
| SALISBURY LABS             | CHARLES CITY       | IA    |
| SALISBURY LABS             | WILMINGTON         | NC    |
| SCHENECTADY CHEM., INC.    | ROTTERDAM JUNCTION | NJ    |
| G.O. SEARLE & CO.          | NORWOOD            | OH    |
| SHARON STEEL CORP.         | FAIRMONT           | WV    |
| SHELL OIL CO.              | DEER PARK          | TX    |
| SHELL OIL CO.              | DOMINGUEZ          | CA    |
| SHELL OIL CO.              | GEISMAR            | LA    |
| SHELL OIL CO.              | MARTINEZ           | CA    |
| SHELL OIL CO.              | NORCO              | LA    |
| SHELL OIL CO.              | WOOD RIVER         | IL    |
| SHENANGO INC.              | NEVILLE ISLAND     | PA    |
| SHERWIN WILLIAMS CO        | ST. BERNARD        | OH    |
| J. R. SIMPLOT CO.          | POCATELLO          | ID    |
| SKELLY OIL CO.             | CLINTON            | IA    |
| SKELLY OIL CO.             | EL DORADO          | KA    |
| SKELLY OIL CO.             | SPRINGFIELD        | OR    |
| SKELLY OIL CO.             | WINNFIELD          | LA    |
| SOLVENT CHEMICAL CO.       | MALDEN             | MA    |
| SOLVENT CHEMICAL CO.       | NIAGRA FALLS       | NY    |
| SONOCO PRODUCTS CO.        | HARTSVILLE         | SC    |
| SOUTH HAMPTON CO.          | SILSBEE            | TX    |
| SPECIALTY ORGANICS, INC.   | IRWINDALE          | CA    |
| SQUIBB CORP.               | NEW BRUNSWICK      | NJ    |



Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                            | CITY            | STATE |
|---------------------------------|-----------------|-------|
| STANDARD CHLORINE CHEMICAL CO.  | DELAWARE CITY   | DE    |
| STANDARD CHLORINE CHEMICAL CO.  | KEARNY          | NJ    |
| STANDARD OF INDIANA             | CHOCOLATE BAYOU | TX    |
| STANDARD OF INDIANA             | DECATUR         | AL    |
| STANDARD OF INDIANA             | JOLIET          | IL    |
| STANDARD OF INDIANA             | TEXAS CITY      | TX    |
| STANDARD OF INDIANA             | WOOD RIVER      | IL    |
| STANDARD OF INDIANA             | YORKTOWN        | VA    |
| STANDARD OF OHIO                | LIMA            | OH    |
| STAUFFER CHEMICAL CO.           | CARSON          | CA    |
| STAUFFER CHEMICAL CO.           | COLD CREEK      | AL    |
| STAUFFER CHEMICAL CO.           | DELAWARE CITY   | DE    |
| STAUFFER CHEMICAL CO.           | EDISON          | NJ    |
| STAUFFER CHEMICAL CO.           | HENDERSON       | NV    |
| STAUFFER CHEMICAL CO.           | LE MOYNE        | AL    |
| STAUFFER CHEMICAL CO.           | LOUISVILLE      | KY    |
| STAUFFER CHEMICAL CO.           | NIAGARA FALLS   | NY    |
| STAUFFER CHEMICAL CO.           | PERRY           | OH    |
| STEPAN CHEMICAL CO.             | ANAHEIM         | CA    |
| STEPAN CHEMICAL CO.             | ELWOOD          | IL    |
| STEPAN CHEMICAL CO.             | FIELDSBORO      | NJ    |
| STERLING DRUG, INC.             | CINCINNATI      | OH    |
| STERLING DRUG, INC.             | MEMPHIS         | TN    |
| STERLING DRUG, INC.             | RENSSELAER      | NY    |
| STIMSON LUMBER COMPANY          | ANACORTES       | WA    |
| ST. PAUL AMMONIA PRODUCTS, INC. | EAST DUBUQUE    | IL    |
| STORY CHEMICAL CORP.            | MUSKEGON        | MI    |
| SUNOCO                          | CORPUS CHRISTI  | TX    |
| SUNOCO                          | DUNCAN          | OK    |
| SUNOCO                          | MARCUS HOOK     | PA    |
| SUNOCO                          | TOLEDO          | OH    |
| SUNOLIN CHEM. CO.               | CLAYMONT        | DE    |
| SYBRON CORP.                    | LYNCHURST       | NJ    |
| SYNTEX CORP.                    | NEWPORT         | TN    |
| TENNECO CHEMICALS, INC.         | CHALMETTE       | LA    |
| TENNECO CHEMICALS, INC.         | FORDS           | NJ    |
| TENNECO CHEMICALS, INC.         | GARFIELD        | NJ    |
| TENNECO CHEMICALS, INC.         | HOUSTON         | TX    |

Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                            | CITY                           | STATE |
|---------------------------------|--------------------------------|-------|
| TENNESSEE VALLEY AUTHORITY      | MUSCLE SHOALS                  | AL    |
| TERRA CHEM INTERNATIONAL, INC.  | PORT NEAL                      | IA    |
| TEXACO, INC.                    | PORT ARTHUR                    | TX    |
| TEXACO, INC.                    | WESTVILLE                      | NJ    |
| TEXAS-U.S. CHEMICAL CO.         | PORT NECHES                    | TX    |
| TOMS RIVER CHEMICAL CORP.       | TOMS RIVER                     | NJ    |
| TRIAD CHEMICAL                  | DONALDSONVILLE                 | LA    |
| TYLER CORP.                     | JOPLIN                         | MO    |
| UNION CAMP CORP.                | DOVER                          | OH    |
| UNION CARBIDE CORP.             | ASHTABULA                      | OH    |
| UNION CARBIDE CORP.             | BOUND BROOK                    | NJ    |
| UNION CARBIDE CORP.             | BROWNSVILLE                    | TX    |
| UNION CARBIDE CORP.             | INSTITUTE AND SOUTH CHARLESTON | WV    |
| UNION CARBIDE CORP.             | MARIETTA                       | OH    |
| UNION CARBIDE CORP.             | NIAGRA FALLS                   | NY    |
| UNION CARBIDE CORP.             | PENUELAS                       | PR    |
| UNION CARBIDE CORP.             | SEADRIFT                       | TX    |
| UNION CARBIDE CORP.             | TAFT                           | LA    |
| UNION OIL OF CALIFORNIA         | TEXAS CITY                     | TX    |
| UNION OIL OF CALIFORNIA         | BEAUMONT                       | TX    |
| UNION OIL OF CALIFORNIA         | BREA                           | CA    |
| UNION PACIFIC CORP. CHAMPLIN    | KENAI                          | AL    |
| UNIROYAL, INC.                  | CORPUS CHRISTI                 | TX    |
| UNITED AIRCRAFT                 | NAUGATUCK                      | CT    |
| UNITED STATES STEEL CORP.       | MUNCIE                         | IN    |
| UNITED STATES STEEL CORP.       | CHEROKEE                       | AL    |
| UNITED STATES STEEL CORP.       | CLAIRETON                      | PA    |
| UNITED STATES STEEL CORP.       | HAVERHILL                      | OH    |
| UNITED STATES STEEL CORP.       | NEVILLE ISLAND                 | PA    |
| UNIVAR CORP.                    | EUGENE                         | OR    |
| UNIVERSAL OIL PRODUCTS CO.      | EAST RUTHERFORD                | NJ    |
| UNIVERSAL OIL PRODUCTS CO.      | MCCOOK                         | IL    |
| UPJOHN CO.                      | LAPORTE                        | TX    |
| VALLEY NITROGEN PRODUCERS, INC. | EL CENTRO                      | CA    |
| VALLEY NITROGEN PRODUCERS, INC. | HELM                           | CA    |
| VAN DE MARK CHEM. CO.           | LOCKPORT                       | NY    |
| VIRGINIA CHEMICALS, INC.        | PORTSMOUTH                     | VA    |
| VULCAN MATERIALS CO.            | GEISMAR                        | LA    |



Table E.1. (Continued). INDUSTRIAL ORGANIC CHEMICAL PRODUCERS

| NAME                              | CITY           | STATE |
|-----------------------------------|----------------|-------|
| VULCAN MATERIALS CO.              | WICHITA        | KA    |
| JIM WALTER CORP.                  | BIRMINGHAM     | AL    |
| WARNER LAMBERT CO.                | HARRIMAN       | NY    |
| WHEELING PITTSBURG STEEL CORP.    | MONESSEN       | PA    |
| WHITE CHEMICAL CORP.              | BAYONNE        | NJ    |
| WILLIAMS COMPANIES                | BLYTHEVILLE    | AR    |
| WILLIAMS COMPANIES                | CATOOSA        | OK    |
| WILLIAMS COMPANIES                | DONALDSONVILLE | LA    |
| WITCO CHEMICAL CORP.              | CLEARING       | IL    |
| WITCO CHEMICAL CORP.              | PATERSON       | NJ    |
| WOBURN CHEMICAL CO.               | KEARNY         | NJ    |
| WOONSOCKET COLOR AND CHEMICAL CO. | WOONSOCKET     | RI    |
| WRIGHT CHEMICAL CO.               | ACME           | NC    |